JOHN H. MacGILLIVRAY
A. E. MICHELBACHER
C. EMLEN SCOTT

TOMATO PRODUCTION IN CALIFORNIA

THIS CIRCULAR GIVES YOU INFORMATION ON:

1. all phases of tomato production—economic aspects, varieties, seed, field seeding, transplanting, irrigation, staking and pruning, harvesting and handling.
2. tomato diseases—their symptoms, prevention and control.
3. insects attacking tomatoes—how to recognize and control them.

CIRCULAR 167
JUNE • 1950

California Agricultural Extension Service
The College of Agriculture
University of California • Berkeley

ERRATUM

The caption for Figure 30 belongs with Figure 31. The caption for Figure 31 belongs with Figure 30.

THE AUTHORS:

Mr. MacGillivray is Professor of Truck Crops and Olericulturist in the Experiment Station, Davis.

Mr. Michelbacher is Assistant Professor of Entomology and Associate Entomologist in the Experiment Station, Berkeley.

Mr. Scott is Agriculturist in Agricultural Extension, Berkeley.

This publication supersedes Extension Circular 104.

TOMATO PRODUCTION IN CALIFORNIA

John H. MacGillivray
A. E. Michelbacher
C. Emlen Scott

CALIFORNIA TOMATO growers have demonstrated their ability to increase acreage and yield per acre under the stimulus of war-time demand for food. During 1942–1945, their somewhat higher production costs due to labor, irrigation, and distant markets were not factors of importance. Now, the grower needs to give consideration to the maintaining of high yields, reducing cost of production (particularly the abandoning of unproductive practices), and producing a quality product which can compete in markets in eastern United States. Emphasis on picking will do much to provide a better quality tomato for canning. Care in picking "green wraps" will insure more even ripening on eastern markets. Tomatoes which have been subject to low field temperatures will be affected by chilling injury with consequent impairment of quality. Accurate and skillful picking of tomatoes is not easy to accomplish, but skill in handling labor will probably return greater profit than will improvement in production practices. Many of the essential points to consider in an adequate tomato program are given in this circular.

ECONOMIC ASPECTS OF THE TOMATO INDUSTRY

The importance of the tomato among our various vegetable crops has increased markedly in the last 25 to 30 years. At present, tomatoes are next in value to white potatoes in the United States. Both the market and processing values of tomato crops have increased, with production taking a decided upward trend during wartime. Tomatoes are most commonly used as a fresh vegetable for salads and as a canned product alone or combined with other foods.

Tomatoes for Fresh Market.— Table 1 shows the value of tomatoes in the country as a whole, and in some of the more important tomato producing states, for the period 1942–1949. In California, about one-seventh of the tomato crop is sold on the fresh market, and nearly one-half of that fresh-market crop is shipped out of the state. The remainder of the crop is used for processing. In the United States, the market crop was grown on almost 250,000 acres and had a value of 87 million dollars. About 20 per cent of the market crop was raised in California.

Most of the California crop is picked in the pink or green stage and is shipped to terminal points where the fruit is ripened before marketing. Tomatoes harvested at this stage are sometimes called "green wrap" when fully green and wrapped. Riper fruits are sold locally.

Table 2 shows that tomatoes are harvested and marketed in California during every month in the year, with the smallest production in March. June to November, inclusive, is the greatest period of production for market, with most of the eastern shipments made during October and November. In the eastern markets, the leading states shipping to New York City and Chicago seem to have little overlap in their period of shipment. At New York City, Florida supplies the market from December to May, Texas from May to August, New Jersey from July to September, and California during October and November. Texas and California supply the December market.

TABLE 1—Production Data for Fresh-market and Processing Tomatoes (Averages, 1942–1949)

	Acreage	Yield per acre	Production	Price	Farm value
Fresh-market					
	acres	bushels*	bushels	dollars	thousand dollars
United States	248,199	121.5	30,151,125	2.90	87,408
California	33,156	182.1	6,038,250	3.64	22,002
Florida	29,663	134.3	3,982,875	5.24	20,876
Texas	84,013	72.4	6,086,625	2.39	14,563
New Jersey	10,875	162.9	1,771,250	2.46	4,355
New York	9,231	209.7	1,936,250	1.74	3,366
Processing					
	acres	tons	tons	dollars	thousand dollars
United States	514,240	5.79	2,979,963	26.58	79,194
California	115,305	8.88	1,024,075	25.91	26,531
Indiana	95,675	5.03	481,413	24.25	11,675
New Jersey	33,488	6.15	205,938	32.60	6,712
Maryland	48,688	4.47	217,850	30.60	6,665
Pennsylvania	28,525	5.54	158,013	29.05	4,590
Ohio	27,538	6.67	183,813	23.41	4,303

Source: Agricultural Statistics for years 1944–1947. U. S. Department of Agriculture, Washington, D.C., and similar sources.
* 1 bushel = 53 pounds.

Tomatoes for Manufacture.— About 85 per cent of California tomatoes are used for canning. The California average for 1942–1949 was about a million tons, grown on about 115 thousand acres. The price received per ton was higher than that in either Indiana or Ohio, but lower than in states farther east. The following data on California's output of the canned product are for the years 1947–1949. The total pack was 26,129,745 cases of various sized cans, divided as follows: tomato juice, 22.9 per cent; catsup, 19.4 per cent; canned tomatoes, 18.6 per cent; tomato paste, 15.6 per cent; sauce, 14.8 per cent; purée, 6.1 per cent; chili sauce, 2.0 per cent; and miscellaneous, 0.6 per cent. During the war, there was a large increase in the production of processed tomatoes in California in spite of the long distance from large consuming markets, the problem of worm control, and, to a lesser extent, the damage from molds and rots.

The weekly receipts of canning tomatoes show that the major portion of the crop is harvested during the last part of September and most of October (fig. 1). The weekly receipts of over 75,000 tons are shown below (1942–1949):

	Tons
September 14–September 20	82,349
September 21–September 27	115,742
September 28–October 4	135,855
October 5–October 11	143,218
October 12–October 18	132,262
October 19–October 25	120,998
October 26–November 1	96,845

TABLE 2—Average Monthly Unloads (at Three Market Terminals) of Market Tomatoes from Important Shipping Areas, 1942–1949

Area of origin	Marketing Month												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
New York City—Number of Cars													
Texas	3	...	...	19	371	917	281	...	...	...	86	117	1794
Florida	173	157	267	304	405	67	1	...	...	1	79	240	1692
California	...	...	...	...	1	3	10	13	76	519	343	22	986
New Jersey	...	...	...	...	...	2	215	401	189	45	2	...	854
Chicago—Number of Cars													
Texas	1	1	1	21	271	453	131	...	...	...	64	72	1015
California	1	1	...	2	3	14	37	14	91	297	160	64	684
Illinois	...	...	...	1	11	17	93	123	132	50	2	1	430
Florida	39	57	92	63	78	5	...	...	...	...	18	61	413
Los Angeles—Number of Cars													
Local	20	1	...	...	...	11	154	485	432	287	225	102	1717
Imperial and Coachella Valleys	96	151	57	111	603	456	22	...	...	...	...	19	1515
San Joaquin Valley	1	...	...	...	1	239	439	56	11	31	28	15	821
San Diego	14	1	...	...	...	3	94	246	125	110	105	65	763
Mexico	86	80	164	182	37	...	...	1	...	...	4	59	613
Santa Barbara and San Luis Obispo	7	...	...	...	...	...	1	12	77	200	147	58	502
Monterey and Santa Cruz	...	...	...	...	...	...	...	3	51	38	12	...	104
California Total	138	153	57	111	604	709	710	802	696	666	517	259	

Source: Unloads of Fresh Fruit and Vegetables at New York City, Chicago, and Los Angeles. Annual Reports for 1942–1949. U. S. Department of Agriculture, Washington, D.C.

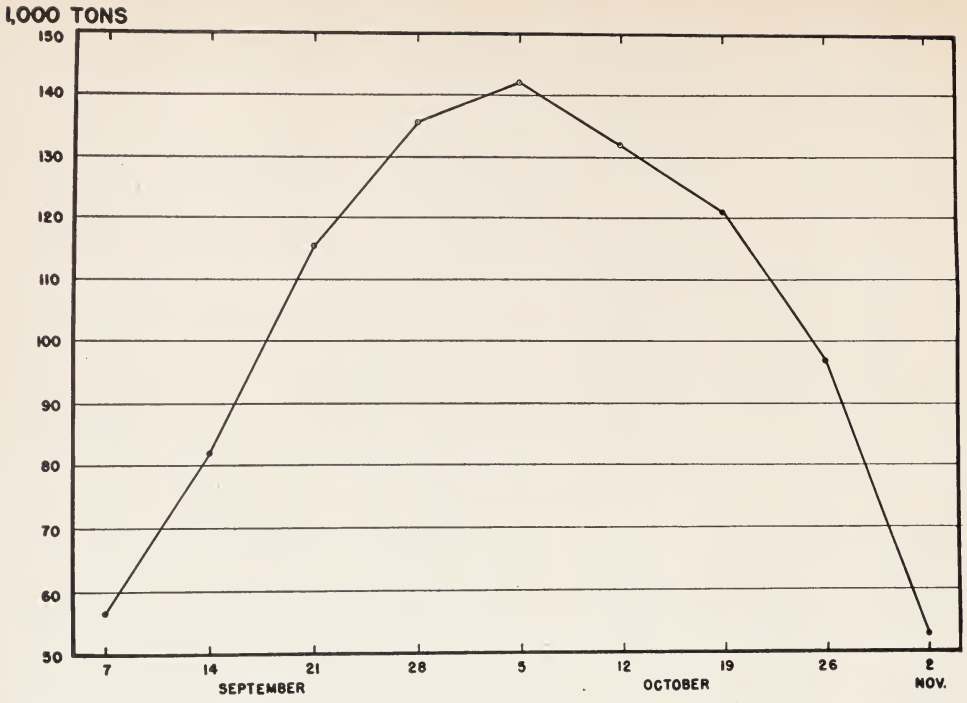


Fig. 1. Weekly receipts of canning tomatoes in California (average 1942–1949). The last date of each week has been used to record data. (Source: mimeographed report of State Department of Agriculture and U. S. Department of Agriculture.)

PRODUCING DISTRICTS

Table 3 shows the average 1942–1948 acreage of market and canning tomatoes by counties, for early spring, early summer, and fall. The groupings for truck crops for fresh market were adopted in 1943 by the United States Department of Agriculture, and correspond to the seasons of the year. Each group in table 3 shows the period when the heaviest supplies of the crop are available. Thus the term "early spring" refers to a peak marketing period during April and the first half of May, "early summer," to the month of July and the first half of August, and "fall," to the period from October to December.

TEMPERATURE REQUIREMENTS

Since the tomato is a warm-season crop, a long growing season is essential—at least 7 months for field seeding and 6 months for the transplanted crop. These months must be frost-free or the crop must receive some protection, as it is sensitive to frost. Tomatoes produce best with average monthly temperatures of 70° to 75° F, but are grown commercially as low as 65° to 70° F and as high as 75° to 80° F. The crop is poorly adapted to average monthly temperatures above 80° F, and fruit is damaged at temperatures near 30° F. Tomatoes are subject to chilling below 50° F, with actual chilling injury at or near 40° F. Such fruits do not show any indication of injury at the time of picking but are frequently responsible for losses at terminal markets due to erratic ripening and rots.

The plants may be barren if the flowers open for pollination when the tempera-

TABLE 3—California Acreage of Tomatoes for Fresh Market and Processing (Seven-year average, 1942–1948)

Area	Counties	Early spring	Early summer	Early fall	Total for market	Total processing	Total all tomatoes
		acres	acres	acres	acres	acres	acres
Desert	Imperial	4,750	....	71	4,821	1,368	6,189
	Riverside						
South Coast	Los Angeles	....	3,657	6,842	10,499	8,819	19,318
	Orange						
	San Bernardino						
	San Diego						
	San Luis Obispo						
	Santa Barbara						
	Ventura						
Central Coast	Alameda	....	600	3,451	4,051	28,505	32,556
	Monterey						
	Napa, San Benito						
	Santa Clara						
	Santa Cruz						
	Sonoma						
San Joaquin Valley	Fresno	....	5,328	3,515	8,843	8,625	17,468
	Kern						
	Madera						
	Merced						
	Stanislaus						
	Tulare						
Delta	Contra Costa	....	336	3,021	3,357	38,787	42,144
	San Joaquin						
	Solano						
Sacramento Valley	Butte	....	135	1,786	1,921	35,615	37,536
	Sacramento						
	Sutter						
	Yolo						
	Yuba						
Other Counties*		....	....	....	....	450	450
Total		4,750	10,056	18,686	33,492	122,169	155,661

*Counties which average less than 300 acres—Amador, Colusa, Glenn, Inyo, Lake, Kings, Placer, San Mateo.

tures are too high or too low. Night temperatures that fall below 55° F for several hours, or day temperatures above 100° F are likely to cause barrenness. The best red color develops with average daily fruit temperatures of 65° to 75° F, while yellowness increases as temperatures go above 80° to 85° F. This effect depends upon how high the temperature goes and how long it stays up. Seed germination is best in a soil temperature near 65° to 75° F, slows down at 50° F, and decreases very rapidly at lower soil temperatures.

Although the tomato succeeds on many soils, soil type and fertility may influence yield, quality, and time of maturity. Good drainage is essential. The tomato plant will root deep unless prevented by plow sole, hardpan, or poor drainage. The history of the land from the standpoint of alkali content is also important, for the tomato is susceptible to alkali injury.

CROPPING SYSTEMS

Since tomatoes are a cash crop, they are sometimes grown for several successive years on the same field. From general rotation experiments, there is considerable evidence that continuous growing of tomatoes will result in a reduction in yield and, frequently, an increase in soil-borne diseases. Farm experience has shown a marked reduction in yield if tomatoes are grown longer than two years in the same field. In the past, a common practice was the growing of alfalfa, barley, tomatoes, and other cash crops. Recently, during high prices, cash crops have been grown more frequently, so that the tendency has been to plant in the following order: tomatoes, sugar beets, barley, and alfalfa. However, nematode damage is more likely to occur when tomatoes and sugar beets follow each other in a rotation. Peas, beans, and spinach, as well as other crops which are not closely related to the tomato botanically, may also be used to advantage in the rotation. Both deep-rooted crops and legumes should be included in a rotation. In general, tomatoes should be grown only once in four years on the same piece of land—obviously in rotation with other crops. Certain diseases and insects often become prevalent when tomatoes are grown continuously. Double-cropping of land with winter vegetables and tomatoes is practical when the tomato crop can be

Fig. 2A. Characteristic fruit of Earliana type. Typical fruit is a slightly flattened sphere, smooth at both stem and blossom ends. Light-colored lines radiate from a medium-sized scar at blossom end of this variety.

irrigated, and when the winter crop comes off early.

Some growers wrongly suppose that tomato plants have an injurious effect upon subsequent crops. Tomato vines and fruits, plowed under, are actually beneficial from the standpoint of added organic matter. The rate of decomposition of the vines in the soil will be increased if the vines are thoroughly disked and cut into pieces before plowing. In the rotting process, considerable fertilizer nutrients become available to crops that follow.

FERTILIZER

Some twenty fertilizer tests have been conducted in the last ten years in important tomato producing areas of the state. A great majority of the tests produced little increase in yield. In most of the state, tomatoes seem less likely to be affected by fertilizer application than do most of our other vegetable crops. Good soils, under good farm practices, are not likely to give increases from fertilizers. Poor, light soils which have been continuously cropped are more likely to respond to fertilizer and give profitable increases. Growers in the Imperial Valley and other desert areas apply some phosphate fertilizer as well as nitrogen to their crop. This practice should be continued at least until results of further fertilizer experiments from that area become available.

The failure of tomatoes to respond to fertilizer is probably related to the fact that they are both a deep-rooted and a warm-season crop. A deep-rooted crop can explore a large volume of soil for moisture and nutrients. During the warm season, factors are more favorable for nutrients to become available, especially nitrogen. In fields where it seems advisable to add nitrogen, an application of 60 to 100 pounds per acre, at planting time or just before the first irrigation, is desirable. In the Imperial and Coachella areas, the application should be both 100 pounds of nitrogen and 100 pounds of phosphoric acid. Fertilizer should be applied in bands on one or both sides of the plant. Locate the bands 4 inches from the plant and 4 to 6 inches below the surface of the soil.

Fig. 2B. Cross-section of Earliana. The core is not pronounced. Fruits are shown natural size. (From Ext. Cir. 104.)

TABLE 4—Tomato Varieties for Different Areas, and Common Spacings

Area	Varieties	Approx. planting distance	Plants per acre
		feet	
FRESH MARKET			
Late Fall or Early Spring			
Imperial and Coachella Valleys	Pennheart, Pearson, Earliana strains, Early Market, First Early, Morse's 498	6 × 2½	2,904
		6 × 1½ (staked)	4,840
Early Summer			
South Coast	Pearson, Stone	5 × 4	2,178
		5 × 1½ (staked)	5,808
San Joaquin Valley	Pritchard, Pearson, Stokesdale	4 × 2 (staked)	5,445
	Earliana, Pennheart	3½ × 1 (staked)	12,446
Early Fall	Pearson, 133–8	5 × 4	2,178
		5 × 3	2,904
CANNING			
North	Pearson, San Marzano	6 × 3 or 6 × 4	2,420 or 1,815
	Early Santa Clara	6 × 6	1,210
South	Pearson, Stone, San Marzano	5 × 4	2,178

VARIETIES

The grower chooses his tomato varieties on the basis of their future use (canning or fresh market), yield, color, fruit setting at various temperatures, shape (for packing), and disease resistance. New varieties are constantly being tested by the University, by seed companies, and by the growers themselves, with special interest in disease-resistant strains. It is to the grower's advantage to make small field trials of new varieties, since by so doing he may improve the market value of his crop.

The following list includes brief descriptions of the most important commercial varieties in California. Table 4 gives the common planting distances.

Earliana types: Several improved strains are now available. The types most generally used are: First Early; Morse's 498; Early Market; and Pennheart.

Plants are smaller than late canning varieties, and require only about one-third as much space per plant. Fruits are red, early maturing, smooth, and globular (fig. 2 *A* and *B*). They are smaller than those of late varieties.

Use: Fresh market. Mainly for extra-early, spring shipments from Imperial Valley and similar desert areas where growers cater to a local market.

Early Market: See Earliana.

Early Santa Clara: Grows vigorously and forms large plants. Fruits are large, flat, uniform in size, but slightly rough (fig. 3), with many seed cells.

Use: To a very limited extent, for canning, in the northern part of the state.

First Early: See Earliana.

Morse's 498: See Earliana.

133-8: Grows vigorously. Dense foliage protects the fruits which are large, scarlet, firm, and semiglobular. (Similar to 133-6, but larger, and with later fruits.)

Pearson: Most commonly used variety in California. Has grown in popularity because it sets fruit over a wide range of temperature. The intervals between pickings for the cannery may be longer with a heavier harvest at each picking. Plants are compact, medium-sized, with some concentration of fruit set. Fruits are medium-sized, with flattened globe, thick skin, and average color (fig. 4).

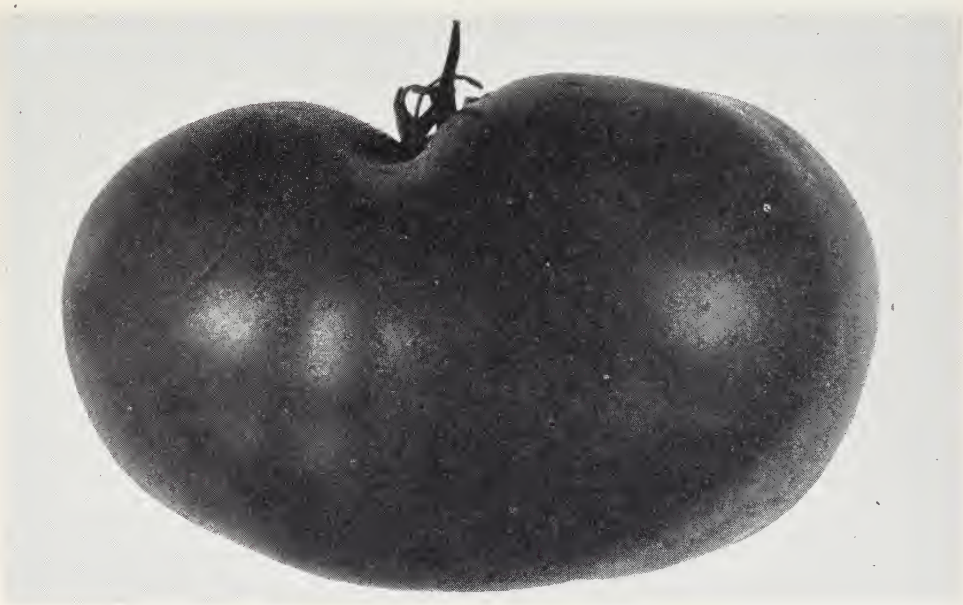


Fig. 3. A typical fruit of the Early Santa Clara canner.

Use: Forms a large percentage of the canning crop. Is also popular as a fresh-market variety.

Pennheart: Developed from a cross of Oxheart and Penn State Earliana. Plant is medium small and "self-topping" (fig. 6). Produces a heavy, early crop. Fruits are globular, scarlet, about three to a pound.

Use: Early fresh-market crop in Imperial and San Joaquin valleys.

Pritchard: Introduced by the U.S.D.A., and formerly called Scarlet Topper. Plants are medium-sized and self-topping. Fruits are nearly globular, thick-meated, with good color.

Use: In the Merced area, for staked tomatoes, and as a local fresh-market crop.

San Marzano: Also called Italian Pear or, sometimes, just Pear, because of its shape. Plants are medium-sized and somewhat open. Fruits are two-celled, grow in numerous clusters, and are small—3½ inches long, 1½ inches wide (fig. 7). Flesh is mild in flavor, with little juice. Color is deep red. Fruits of this variety have tough skins, and will remain on the vine for a long period. Thus, less frequent picking is necessary. The final picking is usually made by cutting the vines at the soil surface and, a few days later, shaking the fruits off. Picking up the tomatoes from the ground is faster than picking them off the vines.

Use: Primarily in the making of canned tomato paste, because it gives a product of thick consistency. Has been used for solid-pack tomatoes to a minor extent.

Stone (Norton): Plants medium-sized, with heavy foliage. Fruits are medium to large, with flattened globes, and about 6 ounces in weight. Color is deep red. The Norton strain is partially resistant to Fusarium wilt.

Use: Grown mainly in the southern part of the state, for shipping and canning.

Fig. 4. Some typical fruits of the Pearson, an important canning variety.

Fig. 5. The stem tip of an indeterminate plant (left) shows that in such plants, the stem continues to grow longer. In the determinate (self-topping) plant at right, growth has stopped with the formation of a fruit cluster, a characteristic of Pearson, Pritchard, and Pennheart varieties.

Fig. 6. A determinate plant of the Pennheart variety.

PRODUCTION INPUTS AND COSTS[1]

Labor and material used, and production costs for tomatoes vary widely in the different areas of the state, and from farm to farm within those areas. The Agricultural Extension Service conducted studies and surveys on inputs and costs in several counties. Their findings for two areas have been summarized, and adjusted to current wage conditions, in the two sample schedules of costs shown in tables 5 and 6.

These examples would apply to production areas of better-than-average conditions, where yields are better than the state average (10 tons per acre in 1947 and 1948). Hours of labor and hourly rates at which labor costs were figured are given so that the grower may adjust them when figuring costs for his own farm.

Table 5 is an example of inputs and costs for the Yolo-San Joaquin counties area, where many of the canning tomatoes are produced. A yield of 14 tons per acre is assumed—an amount usually reached or exceeded by the majority of growers in that region. Costs are shown as for an owner-operator.

Table 6 is an example of inputs and costs for producing staked tomatoes for shipping, in Merced County. Costs are figured on the basis of cash rental for land, a common practice in that district. The yield shown—eight hundred 30-pound packed boxes per acre of shipping fruit, and 8 tons of canning fruit—is approximately what successful growers expect under favorable conditions. It is, however, considerably above the average for the district as a whole. Income from the 8 tons of cannery tomatoes is deducted from total costs to obtain the net cost of producing the shipping tomatoes. The net figure represents costs delivered to the packing shed. Packing costs, boxes, loading, etc., in 1947 and 1948, were about 80 cents to $1 per box.

[1] The data on costs and inputs (tables 5 and 6) were prepared by Arthur Shultis, Agriculturist in Agricultural Extension and Associate on the Giannini Foundation, Berkeley, and B. B. Burlingame, Associate Agriculturist in Agricultural Extension and Associate on the Giannini Foundation, Berkeley.

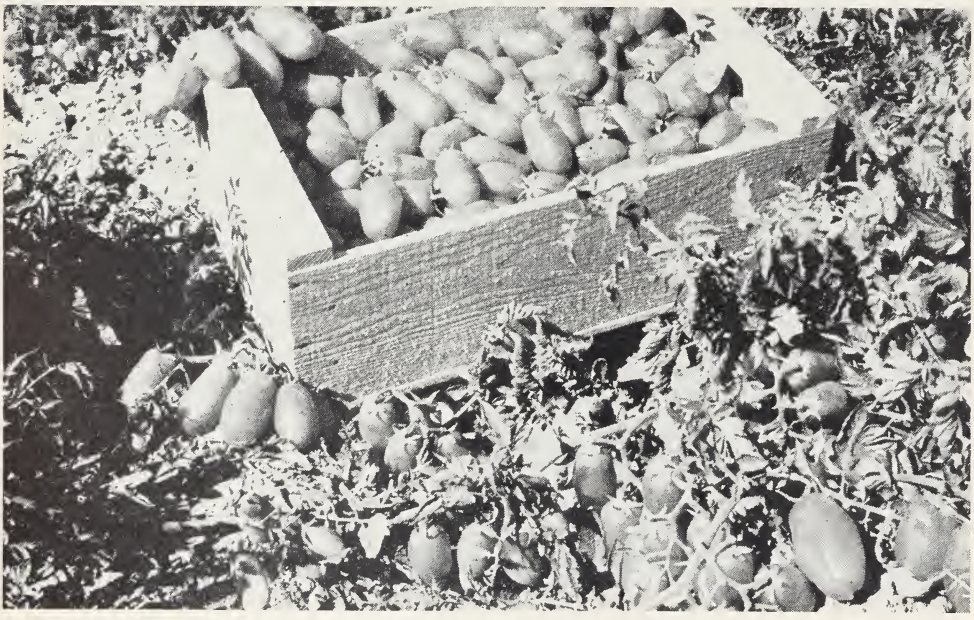


Fig. 7. A vine and box of San Marzano tomatoes.

TABLE 5—An Example of Inputs and Costs for Canning Tomatoes with a Yield of 14 Tons per Acre, Stockton to Woodland Area (transplanted, 3' x 6', 2,400 plants per acre)

	Hours per acre			Costs—dollars	
	man labor	tractor	truck	per acre	per ton
Growing plants	10	.1	.1	8.77	....
Land preparation	4	4.0	...	11.40	....
Transplanting and replanting	5	1.0	1.0	6.95	....
Hoeing and weeding	6	...	...	5.10	....
Irrigation, 4 or 5 times	12	...	...	10.20	....
Cultivation and furrowing, 5 times	4	4.0	...	8.20	....
Fertilizing	1	.5	.1	1.60	....
Pest and disease control	2	.5	.1	2.45	....
Miscellaneous	2	.5	.1	2.45	....
Subtotal cultural labor	46	10.6	1.4	57.12	4.08
Picking, 602 boxes (usually piece rate at 17 cents)	150	...	...	127.50	9.10
Hauling boxes and fruit including loading	15	...	5.0	20.25	1.45
Total labor cost	211	10.6	6.4	204.87	14.63
Irrigation water 24 to 30 acre-inches				7.00	...
Seed and coldframe supplies (1 oz.)				2.00	...
Fertilizers, commercial 400 lbs. at $60 per ton				12.00	...
Pest and disease control materials				9.00	...
Miscellaneous materials				2.00	...
Total material costs				32.00	2.29
General expense				11.84	...
County taxes on land				6.60	...
Repairs to equipment				2.00	...
Compensation insurance				2.00	...
Total cash overhead costs				22.44	1.60

Investment overhead based on 100 acres in farm unit	Original cost	Average value	Interest at 5%	Depreciation		
	Dollars per acre					
General farm buildings	12.00	6.00	.30	.30	....	....
Irrigation system	40.00	20.00	1.00	2.00	....	....
Tillage equipment	10.00	5.00	.25	1.00	....	....
Coldframes	10.00	5.00	.25	2.00	....	....
Transplanting equipment	6.00	3.00	.15	.60	....	....
Miscellaneous other equipment	5.00	2.50	.13	.50	....	....
Land	500.00	500.00	25.00	....	....	....
Total investment	583.00	541.50			....	....
Total depreciation	....	....		6.40	6.40	.46
Total interest on investment	....	....	27.08	....	27.08	1.93
Total all costs	....	....	....	....	292.79	20.91

Labor costs above are based on the following hourly rates: man labor, 85 cents; tractor for land preparation, $2; cultivating tractor, $1.20; truck, $1.50.

The cost of growing plants, as included above, amounts to about $14 an acre with pulling included in transplanting around $5 per 1,000.

If yield were only 10 tons but all costs except harvesting were the same, cost per ton would be about $25.

TABLE 6—Example on Costs of Staked Tomato Production for Shipping in Merced County under 1948 Conditions, Based on Rented Land with a Yield of 800 30-lb. Packed Boxes of Shipping and 8 Tons of Canning Fruit per Acre*

	Hours per acre				Costs—dollars	
	Man labor	Horse work	Tractor work	Truck work	Per acre	Per packed box
Growing plants	80.0	....	....	....	68.00	
Preparing land	5.5	....	5.5	....	11.28	
Planting, replant and pull plants	19.3	....	3.2	1.1	21.90	
Staking	38.0	....	....	2.0	35.30	
Pruning and suckering	80.0	....	....	....	68.00	
Tying	90.0	....	....	....	76.50	
Irrigation, 18 to 20 times	53.0	....	....	....	45.05	
Cultivating and hoeing	17.0	14.0	1.0	....	19.15	
Spraying and dusting (contract)	....	....	....	....	4.50	
Fertilizing (mostly included in cultivation)	2.0	2.0	....	....	2.20	
Miscellaneous (heating, baiting, etc.)	11.0	1.0	1.0	2.0	13.80	
Subtotal preharvest labor	395.8	....	....	....	365.68	
Picking–shipping (725 43-lb. field boxes or 800 30-lb. packed boxes)	280.0	....	....	....	238.00	
Picking–cannery, 8 tons, 380 field boxes at average of 17 cents	....	....	....	....	64.60	
Hauling at $1.50 per ton	....	....	....	....	30.00	
Miscellaneous harvesting	8.0	....	....	2.0	11.80	
Subtotal harvesting labor	288.0	....	....	....	344.40	
Total labor cost	683.8	....	....	....	710.08	
Irrigation water (furnished by landlord)					.....	
Fertilizer (liquid, 10–10–5, and side-dressings)					36.00	
Seed					4.00	
Spray, dust, and bait					10.00	
Miscellaneous (heating oil. tules. repoint stakes [$7])					19.00	
Total material cost					69.00	

General expense					38.95	
County taxes					.20	
Repairs					3.00	
Compensation insurance					7.00	
Other					2.00	
Subtotal cash overhead					51.15	
Rent (cash)					75.00	
Total labor and cash cost					905.23	
Investment:	Original cost	Average investment	Interest at 5%	Depreciation		
	Dollars per acre					
Hotbeds	162.00	82.40	4.12	29.50		
Stakes	135.00	67.50	3.38	54.00		
Tillage, planting and fertilizing equipment	40.00	20.00	1.00	4.00		
Miscellaneous (buildings, heaters, tools)	110.00	55.00	2.75	11.15		
Total depreciation	.....	.....	.....	98.65	98.65	
Total cash and depreciation	.....	.....	.....	.....	1003.88	
Total investment and interest	447.00	224.90	11.25	.....	11.25	
Total all costs					1015.13	1.27
Deduct income from 8 tons cannery tomatoes at $25					200.00	.25
Net cost of raising 800 30-lb. boxes of shipping tomatoes					815.13	1.02

Labor rates per hour: man, 85 cents; horse, 25 cents; tractor, $1.20; truck, $1.50.
* Based upon most common cultural practices.

GROWING THE PLANTS[2]

California, with a considerable range of climatic conditions and months of production, has of necessity made use of several methods to start the crop. The choice of method is dependent upon climate, economic factors, and custom in a given area. The various methods used are: (1) direct field seeding with protection by transparent paper (glassine) cover, or a protection barrier of brush and paper; (2) direct seeding in the field without protection; (3) thin seeding in a coldframe followed by field planting; and (4) seeding in a hotbed with transplanting to coldframe followed by field planting. Field seeding is used at present in a minor way for both the canning and green-wrap crop for fall harvest. Paper covers are used in the Imperial Valley for the late winter crop and in other areas for an early-market crop. Coldframe seeding is used largely for the canning and green-wrap crops. Germination in a hotbed is used for early-market and shipping crops and, to a lesser extent, for the canning crop. Proper germination temperature is critical in the use of any of these methods.

SEED

Good seed is the foundation of a good crop. Buy the best seed available. The amount of seed required depends on plant spacing, plants per acre (see table 4, p. 10), and rate of germination. This rate, under laboratory conditions, is high—about 85 to 95 per cent. It is somewhat lower under actual planting conditions, since it is dependent upon the germination temperatures in different areas. In coldframes, with average germination temperatures, about 50 per cent of the seed will produce plants, but that percentage may be somewhat lower under less favorable conditions.

Tomato seeds average about 10,000 to the ounce. Seed requirement will vary with germinating temperatures; in coldframes, usually 1 pound of seed will supply plants for 10 to 16 acres of canning tomatoes. Hotbed plants grown for closely spaced, staked tomatoes will require about 3 ounces of seed per acre. For field seeding of nonstaked tomatoes, 4 to 6 ounces per acre are commonly used.

When the canning crop is produced from transplants, seed cost is about 5 cents per ton on a 15-ton yield; thus the grower can afford to purchase the best seed even though it costs more. If the crop is grown from seed planted directly in the field, more seed is used, and the cost is somewhat higher. However, it is offset by lower costs in other production items, such as labor for transplanting.

Seed Treatment.—The seed is frequently treated with mercuric chloride to kill seed-borne diseases, and is followed by dusting with yellow copper oxide dust for preëmergence damping-off. When the seedsman treats the seed, this fact is noted on the seed label, to prevent retreatment. The mercuric chloride treatment is made in the following manner. Dissolve 4 large or 16 small tablets, or 1.9 grams of white powdered mercuric chloride in 1 gallon of water. This is a 1 to 2,000 solution. Mix in a wooden or earthenware container. Use a gallon of solution for each pound of seed and use the solution only once. Have the seed in a loosely woven cloth bag about one-third full. Immerse for 5 minutes and then wash the bag and seed in running water for 15 minutes. The bag should be agitated while in the solution to insure thorough wetting. After washing, squeeze the excess water from the seed and spread out in a thin layer to dry.

Mercuric chloride is a deadly poison and should be handled with care.

[2] A more detailed discussion of cannery tomatoes will be found in Extension Circular 160, Tomato Propagation.

An alternative treatment is the use of New Improved Ceresan treatment without yellow copper oxide. Make a solution (1 to 1,200) by dissolving 1 level teaspoon of New Improved Ceresan in 5 quarts of water. Use 1 gallon of *fresh* solution for each pound of seed—use earthenware crock or wooden tub, never a metal container. Have seed in a loosely woven cloth bag about one-third full. Immerse for *exactly* five minutes and agitate the bag so as to insure thorough wetting. Remove bag—do not rinse—squeeze to remove excess water, and spread seed out to dry as quickly as possible. Seed should not be stored in tight containers. Yellow copper oxide treatment is not necessary.

The seed should be free of bacterial canker, Fusarium wilt, and some leafspot diseases. Bacterial canker has resulted in serious loss in yield in recent years and is considered the seed-borne disease which causes the greatest damage. Seed should not be saved from a field containing infected plants. A knowledge of bacterial canker is essential in obtaining disease-free seed, and the grower should purchase his seed with proper consideration of this problem. If a plant bed has bacterial canker infected plants, the disease will be spread by topping the plants. Frequently, the seed is sold by the seedsmen in small, sealed packages and these seals should not be broken until the time of planting. If the packages have a seed lot number, this should be saved for future reference; some growers tack these labels on their plant beds.

Germination Conditions.—Since the tomato is a warm-season crop, low soil temperature may inhibit germination. Adequate germination begins at or above a soil temperature of 55° F, but the germination at 65° F is greater and about three times more rapid. When ideal conditions prevail, plantings should be made at temperatures around 65° to 75° F. Seed is very slow to germinate when planted under conditions of low soil temperature. Growers are inclined to water excessively, but this does not increase soil temperatures. Soil temperature is a critical consideration in starting a tomato crop by the three methods commonly used. Seed planting depth in frames should be about ½ inch.

Effect of Transplanting.—In some of the production methods used, plants are transplanted once and sometimes twice. The effect of transplanting is thus a consideration. When the growth of two plants, one of which has been transplanted, is compared, the retarding effect of this practice on growth is evident. Earlier planting of seed in coldframes is necessary to counteract this effect. Seed may be planted considerably later in the field and produce just as early a crop. In the hotbed-coldframe method, seed is planted about the first of February with field seeding in the same area the last of March or the first of April.

FIELD SEEDING OF CROP

Brush and Caps.—Imperial Valley growers have used the following procedure for early production. Glassine paper caps as well as protection by brush and paper are used. First, beds 18 inches high are made, sloping to the south to take advantage of the more direct rays of the sun. The tomato seed is planted rather generously in hills and is covered with transparent paper (glassine) caps. Twenty-five seedlings may appear under each cap. Day temperatures are greatly increased by this procedure, but night temperatures are only slightly higher. After the seedlings are several inches high, the grower begins to open the cap on the east side to expose the plants gradually to the cooler outside air. This process is continued until finally the cap is removed, after frost danger is past.

Some desert area growers attempt to obtain additional frost protection by the following procedure. In thinning, two of the plants remain erect while another two are bent over and covered with dirt except for their uppermost leaves. In the case of a killing frost, the two erect plants as well as the tops of the two buried plants are most likely to be killed. The buried portions of the plants are then exposed and the new stems come from buds in the axils of the leaves.

Frequently the use of caps is combined with protection from brush and paper (fig. 8). A brush and paper barrier may be prepared as follows: Set posts or grape stakes at intervals of about 100 feet along the top of the bed. Slant them at an angle of 45 degrees except for the end posts which should be left erect and driven deeper. Stretch one strand of wire between the posts and fasten it. Stick pieces of brush (chiefly arrowweed) into the ground below the wire about 6 or 8 inches apart, and slant them over the plant row. Next, place paper about 2½ feet wide on top of the brush, resting it on a single strand of wire. Add more brush on alternate sides of the paper; push some of the brush through the paper. Add a second strand of wire to hold brush and paper in place. Sometimes brush and paper are used without caps. This affords frost protection and increases the temperature around the plants. Caps are used mostly in the spring around Holtville, but the Niland area uses brush and smudges to protect maturing tomatoes from frost in November and December.

Direct Field Seeding.—This procedure is not desirable where tomatoes are to be raised for an early market unless the plants are given additional protection, as in Coachella Valley. Its use is primarily in areas of a long growing season where earliness is not a factor. Fall canning and green-wrap tomatoes

Fig. 8. A tomato crop in Coachella Valley that was started under brush and paper. Unthinned, young plants can be seen between brush and irrigation furrow.

have been produced by this procedure in the north central part of the state. This method requires more accurate timing of operations than do the coldframe or hotbed-coldframe methods. The important considerations are having the soil warm enough for germination, freedom from competing weeds, and the absence of a killing frost after emergence. In the Tracy area, seeding is done about the last of March, with about 6 seeds planted per hill or a row of seed planted with a small seeder. When the plants are 4 to 6 inches high they are thinned out to the distance that is the most desirable one for that area.

RAISING PLANTS FOR TRANSPLANTING

When tomato plants are raised for field transplanting, one of the following methods is employed: (1) Plants are field-grown in a warmer area and shipped to the region where the tomatoes are to be grown. This practice is usually confined to cannery tomatoes. (2) Seeds are planted in a coldframe and the plants are transplanted to the field. (3) Seeds are started in a hotbed, the seedlings are transplanted to a coldframe and finally to the field. The use of coldframes and hotbeds gives better seed germination, but the handling of the plants is more likely to result in infection with mosaic.

Field-grown Plants.—Tomato plants may be grown in a distant area because of warmer weather and shipped to another region for transplanting (fig. 9). Canning tomato plants are produced in Coachella Valley and the crop is grown in the Sacramento Valley. This usually means a better climate for germination and growth, but care should be used to prevent the introduction of diseases and nematodes on the plants.

Fig. 9. Plants produced by seeding in the open. Areas where the soil warms up early in spring can compete with hotbeds in producing cannery tomatoes.

Coldframe Construction.—Coldframes and hotbeds are very similar in structure. The coldframe receives heat only from the sun, while the hotbed also has some artificial source of heat. The following precautions are equally applicable to coldframes and hotbeds: (1) Select an area that is protected from winds and is as warm as possible, with ample sunshine. (2) Treat seed as previously mentioned. (3) The soil should be free from diseases, nematodes, and wireworms, and the area should be clean cultivated. (Petunias and volunteer tomato plants provide a place for the overwintering of russet mites and thus are a source of an early infestation.) (4) Be sure the sand used is free of nematodes. (Sand from creeks is likely to contain them.) (5) Have available an adequate supply of water for sprinkling seed and plants. (6) Prepare beds before planting, and cover them so that the soil will not be excessively wet from recent rains.

Coldframes are made 6 feet wide and about 50 feet long. If an extra amount of heat is desired from the sun, the frames should extend east and west, with the north side about 4 feet high (fig. 10). The sides are usually made of 10- or 12-inch boards, and the ends enclosed with boards. Later in the spring, a north side 16 inches in height is adequate. The frames are sometimes double in width (10 to 12 feet) and extend north and south. The side board is about 10 inches high, with a skeleton frame in the center to hold the cloth covering (fig. 11). Although glass sash is rarely used as a cover, glass does have the advantage of allowing more light to enter, which tends to keep the plants short and sturdy. Unbleached muslin is the most common covering used. This material is low in cost, but it is not efficient in conserving heat and it reduces the amount of light which will reach the seedlings. Pieces of unbleached muslin are sewn together in

Fig. 10. Group of hotbeds used to produce tomato plants. Heating cable and fuse box indicate that electricity is used for heat. Muslin covers frame at left. High side of frame is on the north.

large sheets which have a cord sewn in the edges. This cover is fastened down by lath or tacks, or is hooked on nails driven into the board frame at frequent intervals. The covering should slope sufficiently to shed all rain and thus prevent the wetting of plants and soil surface.

Electric cable is used as an additional source of heat for hotbeds. Light bulbs are sometimes used, but are not an efficient heat source. Other possible means of heating are fermenting manure, steam, and hot water. In many localities, the use of electricity is practical and permits adequate control of the soil temperature through the use of thermostats. As previously mentioned, soil temperatures of 65° to 75° F are desirable during the day, and not lower than 55° F at night.

Seeding in the Coldframe.—Space rows 6 inches apart and plant 20 to 25 seeds per foot. The seed may be sown by hand, but in recent years considerable acreage has been planted by means of a small seeder (fig. 12). Plans for making this seeder are available from the Truck Crops Division at Davis. This equipment permits more accurate sowing of seed, but it is usually advisable to plant sufficient seed so that there is need for a small amount of thinning. Ten to 15 plants per foot of row are ample. Sometimes an area is seeded and a coldframe built over the area. Usually, in this case, the seed is planted in a long row rather than crossways in the bed.

In seed beds, the emerging seedlings are sometimes affected by fungi which cause damping-off or death of the seedlings. These fungi spread under conditions of high humidity, and may destroy large areas of plants. Spray the emerging plants with Semesan, at the rate of 3 to 4 gallons per 100 square feet. Use normal strength—1 level tablespoon per gallon of water. The plants should be sprayed about once a week while they are young. The amount of spray to be used will vary with the size of the plant, but each plant is adequately covered when the

Fig. 11. Coldframe filled with young tomato plants. Muslin cover is off.

first drop of spray runs down the stem.

Another factor in deciding the best method of propagation involves infection with mosaic disease from the use of tobacco. This disease is found in the internal tissues of a diseased plant and cannot be controlled by sprays. Tobacco is usually infected with mosaic virus, and people who use tobacco around plant beds get the virus on their fingers. When the plants are handled in transplanting, they become infected and this results in a reduction in yield. Workers may remove the virus from their hands by washing them with ordinary laundry soap. Tomatoes direct-seeded in the field avoid this danger since there is no handling of the plants.

In the case of a coldframe or a hotbed, some care should be used to obtain good soil for the seedlings. It should be a loam or sandy loam, free from soil-borne diseases and nematodes. Sometimes special soil is mixed, such as one-half sand and one-half loam soil.

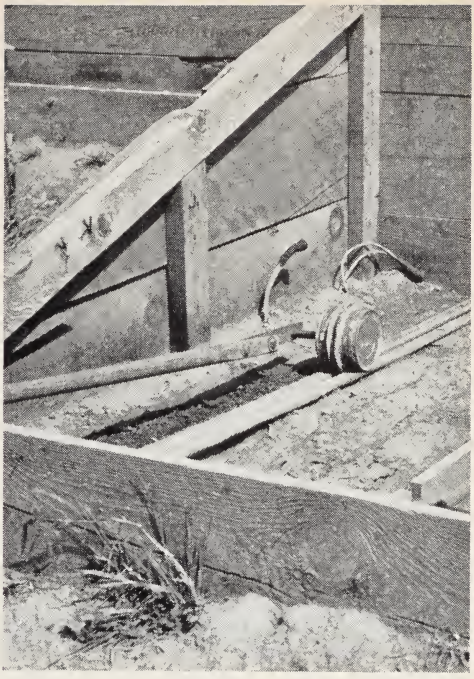


Fig. 12. Small seeding device here used in electric hotbed. (Note cables entering ground.) Seed are spaced so that little thinning is needed.

Hotbed-coldframe Procedure.— A hotbed provides much better conditions for germination than do the other methods, particularly with respect to temperature. The seed is usually sown broadcast at the rate of 1 ounce per 10 to 15 square feet of hotbed space. The seed are slightly covered with soil and then watered. In some areas, before the tomato seedlings push through the soil, it has been the practice to kill all surface weeds with heat from a blow torch.

As soon as the seedlings show their first rough leaves, they are ready to be transplanted to a coldframe. The younger the plants, the less their growth will be retarded by transplanting. Transplanting is worth doing carefully, and should be performed by persons who do not have tobacco juice or virus on their hands. The seedling plants from the hotbed are usually set into the coldframe about 2 by 4 inches apart. Water should follow transplanting, and the frames should be kept covered a few days until the plants have taken root, especially if the sunlight is strong or the weather windy. Once established, the plants should be given only enough water to keep them growing moderately. All watering should be done in the late morning so that the soil surface and the foliage will be dry by evening. It is important that, during the daytime, the frames be ventilated to obtain short plants with thick, stocky stems as well as to reduce the damage by damping-off organisms.

A variation in the hotbed method described above is to transplant the seedlings into small clay pots or into dirt bands from which they can be removed without disturbing the roots. This method, though more expensive, may be profitable to the market gardener who caters to a demand for extra-early fruit on a local market. Often, too, gardeners and seedsmen transplant the seedlings to boxes (flats) about 18 by 24 inches in size and 3 inches deep.

Hardening.—Leave the beds open continually from 5 to 8 days before the plants are transferred to the field unless frost threatens. Apply only enough water to prevent prolonged wilting. This treatment toughens or hardens the plants so that they may be transplanted without severe wilting, which so often kills tender plants in the open field. Well-hardened plants resist frost somewhat better than do succulent ones, and they take root more rapidly. A well-hardened plant is short and stocky, with stiff stems about the diameter of a lead pencil (fig. 13). The stems are frequently purplish and the leaves are dark green. This indicates that there has been a slowing down of growth.

FIELD CULTURE

If there is no crop on the land over winter, the field may be plowed and left rough. The land should be properly leveled so that the plants may be evenly irrigated (fig. 14). In the spring when the soil is at a desirable moisture content, the land should be disked and floated to kill the weeds and to pulverize the surface soil (fig. 15). Much lumpy, poorly pulverized soil is a result of plowing or other operations performed when the soil is too wet. If a soil is lumpy because of improper culture, this will affect crop production and require extra labor in soil preparations. The methods of preparing the field for the plants, and of transplant-

Fig. 13. Bare-root plants ready for transplanting. Note sizes of root systems and stems. The three plants at right are most desirable; they show the good effects of having sufficient room in the coldframe and of not forcing growth.

Fig. 14. Leveling tomato ground with special equipment. Properly leveled ground is essential for adequate irrigation.

Fig. 15. Preparing ground for tomatoes. Disk cuts up green growth, and plank drag levels ground.

Fig. 16. Transplanting tomatoes. Fertilizer distributor is on back of water tank.

Fig. 17. Transplanting machine setting out two rows of plants by cross checking method of marking. Four men are required: tractor driver, two men placing plants, one man to follow machine and make sure seedlings are properly planted.

ing, depend upon the locality and the type of crop.

In recent years, there has been a tendency to place plants closer together in the row. This has led to the practice of spacing only the rows accurately. If the plants are also to be spaced in the row, the distance between plants is marked one way in the field and the planter is run so that when the marks are crossed a plant is put into the ground. The planter marks the rows so that they are properly spaced. If the plants are to be put in by hand, the field must be marked both ways.

Planting distances between rows and plants are governed by several factors. Varieties differ in size of plants—usually early varieties are small and are spaced more closely. Convenience of conducting farm operations, such as cultivation and dusting, is also a factor. The present tendency seems to be toward closer spacing. Transplants are sometimes placed 2 feet apart in the row, direct-seeded tomatoes, as close as 12 to 18 inches. In many cases this closer spacing has resulted in greater yields, but the practice has been used only recently and no final conclusions may be drawn at this time. Time of planting and harvest dates are given in table 7.

Machines used for planting tomatoes are similar to those used for other crops, such as cabbage and peppers. The equipment has a tank for water and may also have an attachment for applying fertilizer or insecticides (figs. 16, 17). Most machines set two rows of plants. A shoe opens a furrow and, as the operator approaches the cross mark, a plant is placed in the furrow and a quart of water is applied. A truck with a water tank is needed to replenish the water supply. Some growers make a small furrow on either side of the plant for an early irrigation.

Transplanting retards growth, and this growth reduction is proportional to root injury. The plants are set a few inches deeper than in the plant bed and are placed carefully so that the roots are not doubled back. New roots develop along the old stem, giving a more extensive root system early in the life of the plant.

IRRIGATION

Tomatoes are a deep-rooted crop—the roots extend to a depth of 6 feet or more in most medium to late varieties. For roots to extend to this depth, the soil must have available water and be free from hard pan or other impervious layers. In a moist, deep soil, roots have been known to go to a depth of 10 to 12 feet. Some of the early, small varieties may not root so deep as the large, late types. Tomato roots extend through a large volume of soil which, if filled with available water, permits considerable growth so that the crop is sometimes raised without irrigation, particularly in the cooler areas of the state. Yield in most areas, such as the Central Valley, may be increased by irrigation as much as 50 per cent, and to a greater extent in the desert areas, such as Imperial Valley.

The number and frequency of irrigations are determined by local conditions, such as type of soil, climate, and competing farm operations. Sandy soils usually need more frequent irrigation than do clay soils since sands hold less available water. Likewise, hot areas need more water than do cooler regions. It is important to supply the plant with sufficient water for a steady growth. Insufficient water is not usually indicated by wilting, but may be detected by a slowing or stoppage of growth and a dark grayish, greenish appearance of the foliage. If a field does not have ample soil moisture at planting time, it would be desirable to make a light irrigation soon after planting. A small furrow close to the plant on either side is desirable to wet the soil close to the roots, for the purpose of supplying moisture and firming the soil around the roots. Subsequent irrigations

TABLE 7—Time of Field Planting, Harvest Dates, and Areas of Production

Area	Field planting*	Harvest begins	Dates most active	Harvest ends	Principal counties
FRESH MARKET					
Early Spring					
Desert area	Nov.–Jan.	April	May	June	Coachella and Imperial valleys
Early Summer					
South Coast	Feb.–March	June	July, Aug.	Sept.	Los Angeles and San Diego
San Joaquin Valley	Feb.–April	late May	June, July	Aug.	Fresno, Merced, Tulare
Early Fall					
North	May–June	Aug.	Oct.	Dec.	Contra Costa, Kern, Sacramento, San Joaquin, Santa Cruz
South	June–July	Sept.	Oct., Nov.	Dec.	Los Angeles, Orange, Santa Barbara, San Diego
Late Fall					
Desert area	Aug.	Nov.	Dec.	Jan.	Imperial Valley
CANNING					
North	Late Apr., May	Sept.	Sept., Oct.	Nov.	Alameda, Contra Costa, Sacramento, San Benito, San Joaquin, Santa Clara, Yolo
South	Apr., May	Aug.	Sept., Oct.	Nov.	Los Angeles, Orange

*Early spring or late fall tomatoes are field seeded; other areas usually use plants which are seeded 10 to 12 weeks before field planting, in hotbeds or coldframes.

(figs. 18, 19, 20) may be made when convenient, but the soil should be filled with available water to a depth of 6 feet just before the first harvest or before the main harvest. There should be little need for irrigation during the picking period. With a preharvest irrigation, the soil will have 8 to 12 inches of available water in the root zone. A soil tube or an auger are desirable for examining the deeper soils for moisture. After a grower has become familiar with a field and its soil types, the wetness of a soil may be roughly estimated by appearance and feel. A wet soil is dark in color and tends to hold together when squeezed in the hand. When tomatoes touch soil that is wet from irrigation water, there will be serious losses from rot. Tomatoes turning red are most likely to be affected.

Tests in the central valleys indicate that canning tomatoes use the following amounts of water for the months listed: June, 3.2 inches; July, 4.5 inches; August, 7.0 inches; September, 5.2 inches; and October, 4.1 inches—a total of 24 inches. The following amounts of irrigation water are recommended for areas where the soil is filled to field capacity from winter rains or a preirrigation: coastal areas, 10 to 12 inches; interior valleys, including desert areas, 18 to 24 inches.[3] Staked tomatoes present a larger leaf area as a result of close planting, and would require somewhat more water. Where tomatoes root deep and thus have a large volume of soil from which to obtain water, there is little likelihood of sudden fluctuations of moisture in the plant with average irrigation. Therefore, there is little evidence to prove, under these conditions, that irrigation causes blossom drop or blossom-end rot in serious amounts.

Cultivation is primarily for the purpose of killing weeds which waste both soil moisture and soil nutrients. Weeds may be cut by shallow cultivating tools with little disturbance to the tomato roots. Time and frequency of cultivation depend upon the number of weeds to be controlled.

STAKING AND PRUNING

The tomato plant first forms a primary, semi-erect stem, then develops secondary stems from the buds in the axils of the leaves. Without pruning, the common tomato forms a prostrate bush shape, having several stems. Under the special form of culture known as staking and pruning, the side shoots, or most of them, are removed as they appear. They should be pulled out of the axils of the leaves, not pinched with the fingernail or cut with a knife. Pinching or cutting is likely to spread virus diseases, such as mosaic. Such diseases cause decreased yields in proportion to the earliness of infection. By pruning, the growth is limited to the main or central stem, which is kept erect by tying it at intervals to stakes or to wires stretched between stakes. Tomatoes grown under this method of culture are referred to by growers as "stick" or staked tomatoes (figs. 21, 22). The fruit cluster forms on one side of the stem, and the plant should be tied so that the clusters will not be against the stake, to prevent fruit injury. If a variety that has a small plant is selected, it may be desirable to have two main stems so that the foliage will better protect the fruit against sunburn. Sometimes two stems will also increase yields, particularly if wider spacing is used. There is some evidence that pruning and training to only one stem cause decreased yields. Plants to be staked and pruned may be spaced 12 to 18 inches apart, and sometimes are planted as close as 9 inches, with rows 3 to 4 feet apart. This arrangement gives three or more times as many plants per acre as does an early variety grown without staking and pruning. Staking and pruning

[3] Doneen, L. D., and John H. MacGillivray. Suggestions for irrigating commercial truck crops. Calif. Agr. Exp. Sta. Litho. 1943.

Fig. 18. Tractor making an irrigation furrow in tomato field.

Fig. 19. On many soils, well-filled furrows will increase lateral penetration of water and insure wetting of all soil between rows.

Fig. 20. Irrigating tomato field by use of siphon to draw water from head ditch. Siphons are light in weight and easily moved. Pipes, air hoses, or other devices are also placed through banks for the same purpose.

experiments indicate that this practice results in more plants per acre and a greater production of early fruits per acre. Fruits kept off the ground may be of better quality and are easier to pick. Staking procedure involves higher costs of production per acre for labor, plants, and materials. Growing staked tomatoes is a specialized procedure and is used in Merced for shipping and in other areas where the fruit is sold on near-by or local markets.

UNSATISFACTORY FRUIT SETTING

Pollination, fruit setting, and tomato yields are closely related. The fruit is developed at the expense of food manufactured by the plant foliage; therefore, it is of primary importance to produce a large plant which will have many blossoms. Adequate soil nutrients or fertilizer constituents, irrigation, and other environmental factors all affect plant growth, number of fruits and their size, and, consequently, yields. There is also evidence that temperatures are an important factor where blossoms fall from the plant without forming a fruit. Failure of the pollen to germinate, thus affecting fruit-set, may be influenced by high or low temperatures. Night temperatures below 55° F for several hours, or day temperatures of 100° F, tend to prevent fruit setting; 70° to 80° F is more favorable.

There has been considerable publicity recently about the use of hormone sprays to set tomato fruits.[4] Several compounds have been used, but sodium para-chlorophenoxyacetate seems as reliable as any when used at a concentration of 50 parts per million. Hormone treatments in general have proved effective in setting fruit on plants grown for early-market tomatoes when weather conditions were unfavorable for natural setting. However, work on hormone sprays for setting tomatoes is still in the experimental stage. Recommendations for general field spraying cannot be made at present. Spraying tomato plants with hormones may be dangerous. Some trials have shown serious injury to foliage and some to fruit.

HARVESTING AND HANDLING

Tomatoes are picked in several stages of maturity, depending upon how they are to be marketed. As a fruit matures, there are changes in its color, texture, and taste.

Fresh-market Crop.—After the fruit forms, it makes most of its growth as a green fruit. After maximum size has been obtained, there are changes in the color and feel of the fruit. Picking at the mature green stage is not an easy matter, and the grower should look for the following characteristics of mature green fruit: (1) maximum size for the variety; (2) development of a corky stem scar; (3) on an immature fruit, the skin can be rubbed off, but this is not true of a mature green; and (4) when a mature green fruit is cut with a sharp knife, the seeds are hard enough not to be cut. The next stage is "breaker," or the first coloration around the blossom end. This is followed by the so-called "pink" stage and then the fully red stage when the fruit is entirely ripe. As the fruit ripens, it becomes more soft in texture and the pulp around the seeds becomes gelatinous in consistency. The green wraps and some pinks are used for shipment to distant markets. Local markets use both the pinks and fruits which are almost ripe. The canning industry prefers the ripe, fully red tomatoes.

Rate of ripening and color development are affected by temperature. Temperatures may be so high that the

[4] Further information may be obtained by a request to the Truck Crops Division, Davis.

development of the red pigment is retarded or prevented. Average daily temperatures of 65° to 80° F are thought to produce the best color, but the air temperatures may be higher if the fruits ripen in the shade of the leaves. Shipping tomatoes are sometimes chilled in the field due to low fall temperatures, such as 40° to 45° F. This does not affect the appearance of mature greens at picking, but may cause serious losses from decay during transit and ripening. The exposure of the fruits to low temperatures in the field may make the tomatoes more subject to harmful effects from low temperatures after they have been harvested.

Green Wraps.—These fruits for the fall crop are usually planted to reach picking stage near the latter part of September. The fields are picked at least once each week and sometimes the riper tomatoes are sold to local markets or canners. After the fruits arrive at the packing house, they are washed, waxed, and sized. They are wrapped in paper and packed in Los Angeles lug boxes with a net weight of at least 30 pounds. Three layers of fruit are packed in these lugs, and the size of the fruit is designated by the number of fruits in the top layer. For example, a top layer having five rows of tomatoes extending crosswise and six rows extending lengthwise would be designated as a

Fig. 21. Left: Staked tomatoes. Note the stake by each plant, and wire support. The plants are closely spaced. Fig. 22. Right: Imperial Valley staked tomatoes which were started with protection by brush and by paper caps. Large stakes were used earlier for supporting brush.

Fig. 23. Packing green-wrap tomatoes in grower's packing house. Each box contains four baskets.

5 × 6 pack. The Merced early summer pack of tomatoes is usually 6 × 6 or smaller, while the fall packs of other areas are 6 × 6 or larger. The Imperial and early spring crop is packed in 3-quart till baskets (fig. 23) with four baskets per crate.

Ripening.—Fruit picked mature green ripens and colors up within one to three weeks, according to storage temperature and the degree of maturity when picked. Upon reaching market, the fruits are unwrapped; those showing sufficient color are sold at once, and fruit still green or only partly colored are placed in special ripening rooms. In gathering mature green tomatoes, careless pickers take some that are not mature. These are a distinct disadvantage, as they increase the unevenness of ripening, and some tomatoes may even be a total loss. Tomatoes picked in the turning stage, when they show a little pink at the blossom end, are of more uniformly high quality when artificially ripened than are those picked green. The storage period is also shorter for fruits picked at this slightly pink stage.

Temperatures of 55° and 75° F are the extremes for ripening. A temperature range of 65° to 70° F favors good color development. A range of 70° to 75° F will give most rapid ripening. The maximum storage life of tomatoes is obtained with a temperature of 55° F. They can be held for not more than three weeks at this temperature and, upon removal to a temperature of 70° F, will attain ripeness in another week. If stored at less than 50° F for more than a few days, the fruit may not develop good color or flavor when removed to higher temperatures and may even decay before reaching an edible condition. Prolonged cold storage of either green or ripe tomatoes is therefore not recommended.

Ripening of the immature fruits in storage can be accelerated by adding small amounts of ethylene gas to the air. A concentration of 1 part ethylene to 2,000 to 4,000 parts of air seems ade-

quate. Though *explosive* in mixtures of 1 to 3 with air, the gas is not dangerous at these recommended low concentrations. Use of ethylene will reduce by four to seven days the time required to ripen tomatoes. The gas is obtained, in compressed form, in steel cylinders from which the measured amount is discharged into the ripening room each day. The room must be approximately airtight to prevent too rapid a loss of the gas. As oxygen is also essential for normal ripening, fresh air should be admitted each day. Favorable temperatures must be maintained in the ripening room even when ethylene is used.

Canning Tomatoes.—The processing industry desires fruits of good color. Tomatoes are graded, and must meet the specifications for the canning grade in the State Agricultural Code. The fruits are usually picked directly into 50-pound lug boxes, but sometimes pails or similar containers are used for carrying them to the boxes. Proper supervision of the pickers so that the loads will comply with the state canning grade is important from the standpoint of income. Indiscriminate picking of tomatoes causes the inspectors to reject loads which must then be resorted or discarded at considerable financial loss to the grower.

YIELDS

The yield depends upon fertile soil, a good plant stand, proper timing of cultural practices, length of harvesting season, and prevention of damage by insects and diseases. Tomatoes produced for a spring shipping crop, as in the Imperial Valley, yield about 4 tons (or 250 lug boxes of 30 pounds each) of packed-out fruit to the acre. Other shipping areas produce slightly higher yields, or about 5 tons per acre. The tomatoes harvested in the fall in the southern part of the state produce the greatest yield for fresh shipment.

Canning tomatoes, however, are much more productive. While the state average yield is 10 tons per acre, the grower's goal should be from 15 to 25 tons.

PROBLEMS OF THE TOMATO GROWER

California as a canning state has the advantages of high yields, better-than-average color, "low mold count" of tomato products, and the opportunity, in periods of good prices, to can tomatoes after the crop has been killed in the East by frost. Damage to fruits by insects is a much more serious problem in the West, and tomato products with too high an "insect fragment count" may be seized and destroyed by the Federal Pure Food authorities. Our western tomatoes are low in active acidity and consequently our processing times must be longer than are those in the East. This causes breaking of the tomatoes in the can. Brokers and wholesale buyers of canned tomatoes want the fruits to come out of the can in a whole condition, and will pay a premium for this type of canned product. Whole canned tomatoes are spoken of as "solid pack," and for many years this type of pack has been small because all fruits were not suitable. Our advantages may be greater in the production of tomato products, such as juice, purée, paste, catsup, chili sauce, etc., rather than canned tomatoes.

Our fresh tomato shipments are mostly made in the fall to supply eastern markets after local frosts and before the arrival of shipments from Florida and other southern states. Transportation losses are large on shipping tomatoes because of field chilling, difficulty of controlling refrigerator car temperatures at around 60° to 70° F, and length of period in transit to market.

DISEASES OF TOMATOES

Tomatoes in California are subject to many diseases, any one of which may cause considerable loss to the grower. This section discusses the principal diseases, describes their symptoms, and suggests controls and preventive measures where feasible.

Damping-off is caused by soil-inhabiting fungi, including Pythium, Rhizoctonia, Sclerotinia, and Fusarium. The organisms enter the stems of young seedlings at the soil surface, and destroy the stem tissue. This disease usually shows up in small areas, but spreads rapidly, and unless checked, may destroy the entire bed.

Symptoms.—The first symptom is a slight drooping at the tips of the young leaves and a general loss of turgidity. Marked wilting soon develops, and the stems appear water-soaked at the soil surface. Diseased plants soon bend at the soil line and fall to the ground. If humidity is high, the weblike threads of the fungus grow over the fallen plants.

Preventive measures.—Damping-off can usually be controlled satisfactorily by seed treatment and postemergence spraying. Seed that has been treated with corrosive sublimate, washed, and dried, should be treated again with yellow copper oxide dust at the rate of 1 teaspoon per pound of seed. If seed has been immersed in New Improved Ceresan, no other treatment is necessary. After the seedlings are up, spray at intervals of 7 to 10 days with normal Semesan solution—1 level tablespoon Semesan stirred into 1 gallon of water.

Humid conditions and inadequate ventilation favor development of damping-off. Locate plant beds on well-drained soil covered with about ¼ inch of nematode-free sand. This arrangement allows the surface to dry more quickly so that conditions are less favorable to the disease. After seedlings emerge, water the beds sparingly, and keep them well ventilated. When climate permits, open the beds by midmorning, water them, and leave them open until well into the afternoon. Do not water again in the afternoon, before covering the beds, even if the surface soil appears dry. Keep the surface as dry as possible whenever the plants are covered.

Fusarium wilt is caused by the soil fungus *Fusarium oxysporum* f. *lycopersici.* It is a serious problem in certain regions where soil temperatures are high, and causes some losses in the early staked crop of the San Joaquin Valley and in the canning crop of the Delta and the Sacramento Valley. In general, it is not serious in coastal areas. This species of Fusarium attacks only tomatoes. It remains in the soil from year to year, and enters the plants through their roots. It is favored by soil temperatures of 80° F and above, and is most severe on the lighter, well-aerated, well-drained types of soil that heat up quickly. It may be brought into fields on infected transplants and may also be seed-borne.

Symptoms.—Leaves of infected plants turn yellow, usually on one side of the plant at first. Later, the plant dies prematurely. The woody cylinder of the stem turns light brown, but it does not crack open, nor is the pith destroyed, as with bacterial canker. Do not confuse Fusarium wilt with Rhizopus canker, in which one branch turns yellow, and has an early-ripened and rotted fruit attached to it.

Preventive measures.—Plant wilt-resistant varieties where soil is infested. (For a discussion of varieties, see pages 11–12.)

Verticillium wilt is caused by the widespread soil fungus *Verticillium albo-atrum.* This disease is most serious under the cool conditions of the coastal districts, and is most prevalent in fields previously planted to tomatoes. The fungus persists in the soil from year to year. It infects other plants besides tomatoes, among them strawberries, cotton, and young stone fruit trees.

Symptoms.—Older leaves die prematurely, and when the stem is cut near the ground, a brown discoloration is seen in the woody cylinder. The premature dying of the leaves exposes the fruits to sunscald. Infected plants may wilt temporarily following heavy irrigation.

Preventive measures.—Crop rotation is advisable. Although not resistant to infection, Early Santa Clara and Pearson varieties show some tolerance to Verticillium wilt. Bonnie Best and San Marzano varieties are more severely injured.

Late blight is caused by the fungus *Phytophthora infestans*. It sometimes results in losses from fruit infection in the late fall crop in San Diego, Orange, Los Angeles, Ventura, and Santa Barbara counties after early fall rains. Infection also occurs in plant beds in the spring.

Symptoms.—Brown or black blotches appear on the leaves and stems (fig. 24). These spots enlarge rapidly, and cause blighting of the tops. Brown areas also appear on the green fruits. These areas are lobed at the margin and slightly sunken, with a somewhat corrugated surface that is firm and hard to the touch (fig. 25). These lesions enlarge over half or more of the fruit surface, sometimes with three or four lesions on the same fruit. It is difficult to detect the beginning of infection when the green fruit is packed; the lesions develop rapidly in transit and during storage in the ripening rooms. This fungus usually affects only the outer walls of the fruit where it produces a shallow, dry rot. However, other rot-producing organisms often enter the fruit through the blight lesions.

Under very moist conditions, a whitish, velvety outgrowth of the fungus appears on the leaf and stem lesions. This

Fig. 24. Left: Symptoms of late-blight infection on tomato leaf. Blotches are at first water-soaked, later become greenish-brown or black. A white mold forms on undersurface. Fig. 25. Right: Symptoms of late blight on tomato fruit. Small, greenish-brown blotches enlarge and later become dark brown. Interior tissues become water-soaked and soon decay.

moldy growth is formed by the sporophores and spores of the fungus. The spores may be spread by wind and infect other plants.

Preventive measures.—Late blight may be prevented by spraying or dusting with a copper fungicide. Since the fungus may remain in old, overwintered tomato plants and be carried from them to seedlings or to young plants in the plant bed, the grower should destroy all overwintered tomato plants in the neighborhood of his plant beds.

Early blight is caused by the fungus *Alternaria solani.* It sometimes occurs in the plant beds in early spring after prolonged wet weather, and occasionally appears on the maturing crop along the coast.

Symptoms.—Small, dark brown spots appear on the leaves (fig. 26). When closely examined, these show a series of concentric rings. Black cankers also appear on the stems of young plants, and small spots or large, brown, stem-end lesions show up on the green fruits late in the season (fig. 27). Infected plants may also be dwarfed, and what few fruits form may ripen prematurely.

Control.—Spray plant beds with yellow copper oxide—1½ pounds per 100 gallons of water. This will check the disease.

Preventive measures.—Do not use plants from infected beds, particularly if they show any stem infection. If infected plants are set out in the field, the stem lesions continue to enlarge, finally girdling and weakening the stem. This produces collar rot (fig. 28), which weakens the stem so that it may break when the plant is whipped about by wind. If early blight has previously caused trouble in a planting area, move the plant beds to a new location.

Fig. 26. Top: Early-blight leaf infection. This disease occurs in plant beds in wet seasons.
Fig. 27. Bottom: Early-blight lesions on green tomato fruits.

Fig. 28. Collar rot resulting from plant-bed stem lesions of the early-blight fungus, **Alternaria solani.** The stem eventually breaks as the plant is whipped about by the wind.

Pleospora rot, caused by *Pleospora lycopersici* (*Macrosporium* sp.), affects the stem end of the ripening fruit (fig. 29). Infection enters through cracks and wounds near the stem end, where a firm, dark brown spot develops. (Other fungi may also infect growth cracks and cause rotting of ripe fruits.) Temperatures between 65° and 70° F favor most rapid development of the rot. It has caused considerable loss in November and December shipments to eastern markets.

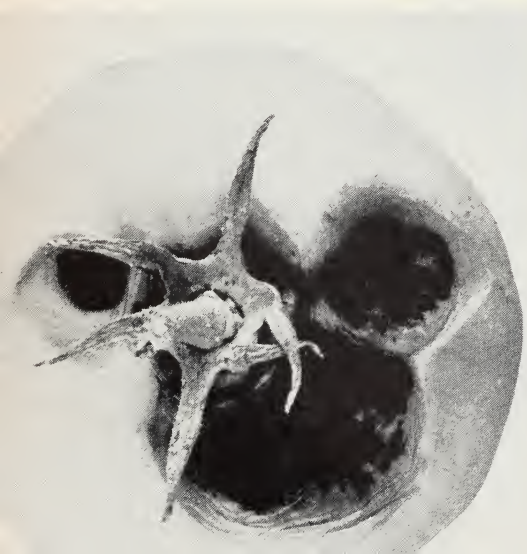


Fig. 29. Pleospora rot. This stem-end rot causes some loss in late fall shipments to the east from the Salinas Valley.

Rhizopus fruit rot and stem blight is caused by a fungus which enters the fruit through growth cracks, or openings caused by worm damage or other injuries. It usually attacks fruits under heavy foliage in areas where humidity is high. The canning tomato crop in the interior valleys suffers considerable damage from this disease.

Symptoms.—Infected fruit becomes a soft, watery mass, then loses the water contents and dries up on the stem (fig. 30). The fungus may spread from the fruit to the fruit spur, thus blighting the entire cluster. It may also continue into the main branch where it forms a long, dark brown, sunken canker. Similar cankers may occur where infected fruits touch a near-by stem, sometimes girdling the stem. Once the fungus enters a main branch of the plant, the leaves show a

Fig. 30. Rhizopus rot of the first fruits to ripen. From the rotted fruit, the fungus may invade the fruit stem and finally girdle the main shoot.

yellowing and blighting that might be mistaken for Fusarium wilt.

Preventive measures.—Irrigate carefully, to keep excess moisture from collecting under the plants. Remove rotten and damaged fruits at the first picking. This will help keep down losses.

Buckeye rot is caused by a soil-inhabiting fungus, *Phytophthora capsici.* It occurs on green fruits that have been in contact with wet soil or irrigation water, particularly in the fall green-wrap crop in the Brentwood district.

Symptoms.—Lesions are light brown, firm, leathery, have lobed margins and, sometimes, broad, concentric zones (fig. 31). These lesions enlarge rapidly and soon involve the entire fruit.

Fig. 31. Buckeye rot caused by **Phytophthora parasitica** may occur on green fruits in contact with wet soil or irrigation water in the Brentwood green-wrap crop. This rot may resemble late blight, but foliage is not affected.

Leaf mold.—The leaf mold caused by *Cladosporium fulvum* usually appears only on greenhouse tomatoes, although it may occasionally occur on staked tomatoes in fields near the coast.

Symptoms.—Large, yellow patches appear on the upper surface, with a brown, velvety growth on the lower side. Infected leaves die prematurely.

Preventive measures.—Clean up and disinfect the greenhouse before plants are set out. Keep the relative humidity low by adequate ventilation and heating. Irrigate properly. These measures will cut down leaf-mold losses.

Bacterial canker is caused by a bacterial organism, *Corynebacterium michiganense*. It causes stunting and early dying of the plants. Infection is carried both within and on the seed, and spreads under plant-bed conditions through the normal process of handling the transplants. The disease may also be spread by the cutting knife used in topping plants, by handling during transplanting, and by the practice of immersing freshly pulled transplants in water. Field carry over of infection does not seem to occur in California.

Plants that show severe infection early in the season seldom produce any fruit of marketable size. Plants infected less severely may continue to grow and produce some fruits fit for market.

Symptoms.—The disease first shows up in a sudden wilting of the leaflets (fig. 32), often on only one or two branches, followed by a rapid dying of the wilted leaves. Wilted leaflets show first a pale green color, later a light tan, as they dry up. This is in contrast to Fusarium wilt, where the leaves turn yellow. Bacterial canker may also be distinguished from Fusarium wilt by the soft, mealy conditions of the interior tissues, as contrasted to the rather narrow, darker brown, firm, discolored tissue lying just under the stem surface of plants infected with Fusarium wilt. Infection is often confined to one, or a few, shoots on one side of the plant. These shoots may die, or be severely stunted, while healthy branches on the other side of the plant may continue normal growth, giving the plant a one-sided appearance.

Yellowish-white streaks frequently appear on the stems and petioles, especially on the tender upper shoots where infection is close to the surface. These streaks often crack when the tissue dries, and form open cankers—one of the main symptoms of this disease (fig. 33). The interior of diseased stems is yellowish to brown, and mealy, especially at the leaf nodes. The pith may be easily separated from the woody part. The infection also spreads into the leaf petioles, from which a yellowish ooze may be squeezed when a leaf is broken off.

The canker bacteria may also penetrate from the stem tissue into the fruit and sometimes the seed, without being noticeable. Fruits from severely diseased plants occasionally show a yellowish color in the seed cavity, which swarms with bacteria.

Preventive measures:

1. Buy seed from a reliable seedsman.

2. Save seed only from disease-free fields.

3. Treat seed before planting. Place the seed in a thin cloth bag and immerse it for 5 minutes in a solution of 1 part New Improved Ceresan to 1,200 parts water. Use 1 gallon of solution for 1 pound of seed. Another disinfectant may be used—1 part bichloride of mercury (corrosive sublimate) to 2,000 parts water. Soak seed for 5 minutes, with frequent agitation. Rinse in running water for 15 minutes. (The best method is to tie the open end of the bag to a faucet and turn the water on with enough force to wash the seed rapidly.) Spread the seed out to dry. (These treatments also help to control preëmergence damping-off.) When seed is dry, dust it with yellow copper oxide—1 level teaspoon per pound of seed. This will help to control preemergence damping-off.

Fig. 32. Effect of bacterial canker on seedlings. Right: Wilting leaves are first symptoms. Left: Later stage, with cankers on stem.

4. Locate plant beds in soil that has not previously been used for tomatoes. If old plant-bed lumber is used, disinfect it with formaldehyde (1 pint to 5 gallons of water) or copper sulfate (1 pound to 10 gallons of water).

5. Do not use plants from beds showing even a trace of canker. When buying plants, make reasonably sure that the grower took precautions to keep out this disease.

6. Do not top plants; the cutting knife may spread disease.

7. Do not immerse transplants in water while they are waiting to be set out in the field.

Fig. 33. Left: Symptoms of bacterial canker on young plant found in field. Note cankers on stems and dead leaves on side branches. Fig. 34. Right: Field in Sacramento Valley showing tomato plants severely injured by bacterial canker.

Bacterial speck is caused by the organism *Bacterium punctulans* which may be carried on the tomato seed.

Symptoms.—A black spotting of the leaves (fig. 35) occurs in plant beds under humid conditions and where overhead watering is practiced. The spots are greasy, and do not have the concentric lines that show in the lesions of early blight. This disease is not serious, and disappears after the plants are set out in the field.

Another type of leaf specking sometimes appears in the plant bed. This is not caused by a parasite, but may result from lack of some soil nutrient. The spots are small, brown, and closely crowded. They appear between the leaf veins.

Spotted wilt is caused by a virus carried into the tomato field by flower thrips. It infects ornamentals, truck crops, and weeds, including celery, lettuce, pepper, and horse bean, among the crops; calla, aster, nasturtium, tuberous begonia, gloxinia, cineraria, calceolaria, delphinium, dahlia, petunia, and zinnia, among the ornamentals; and nettle, chickweed, Jimson weed, wild lettuce, and mallow, among the weeds. Infected plants of any species may be a source of infection for tomatoes.

Fig. 35. Bacterial speck on leaflets of young plants in field.

The disease causes tremendous damage to tomatoes in the coastal regions, possibly because there is no freezing weather to cut down the reservoir of infection in winter crops, ornamentals, and weeds. Or it may be that there are more flower thrips in those districts. Serious damage has occurred in the interior valleys only when the disease has been brought in on transplants grown near the coast, or has spread from near-by, year-round truck crops or plantings of ornamentals. Late-season infection may occur to a limited degree in the Delta region and the Sacramento Valley, probably caused by infective thrips blown in from the Bay region.

In parts of the coastal districts, spotted wilt is so prevalent that tomatoes cannot be grown profitably. In general, however, the disease is scattered, and may affect 10 to 25 per cent of the crop by early infection, with considerable increase later in the season. The virus does not seem to spread from one tomato plant to another in the field, but is brought in by infective thrips from outside sources of infection. Frequently, spotted wilt occurs in plant beds which are located near ornamentals and home gardens, which are sources of infective thrips.

Symptoms appear two to three weeks after infection occurs. This disease causes a sudden blighting and death of the tips of vigorously growing tomato plants (fig. 36). Careful examination shows that blighting is preceded by numerous circular dead spots on the young leaflets, or by a bronzing (fig. 37) of the upper surfaces of these leaflets. Dead spots or streaks also appear on the leaf stalks and the stem. Occasionally, such plants are killed outright, but usually they remain alive, making little further growth and being greatly dwarfed and rosetted. The leaflets may show severe, mosaic symp-

Fig. 36. Left: Leaflet shows circular brown spots characteristic of early stages of spotted wilt. Right: Streaking of stem and petiole, darkening of pith, and leaf blighting caused by spotted wilt.

Fig. 37. Yellowing, bronzing, and apical burning of tomato leaflets, caused by spotted wilt.

toms. Plants thus affected bear no crop.

If young plants are infected in the plant bed, they show numerous small, circular dead spots on the leaves, and die quickly. Plants noticeably infected at this early stage seldom survive transplanting.

When older, bearing plants are infected, the blighting of the growing points may or may not occur. But the fruits are clearly marked by circular patterns. On green fruit, the circles may be light and dark green (fig. 38). On ripening fruit, circular yellow spots may appear on a red background, or circular red spots on a yellow background. This is especially undesirable on late-season fruit to be shipped to eastern markets.

When plants are infected with both the mosaic virus and the spotted wilt virus—a common condition late in the season—the spotted wilt symptoms are more severe, but the spots and patterns on leaves and fruit do not have the characteristic circular shape. There are extensive and irregular areas of dead tissue on and in the fruits.

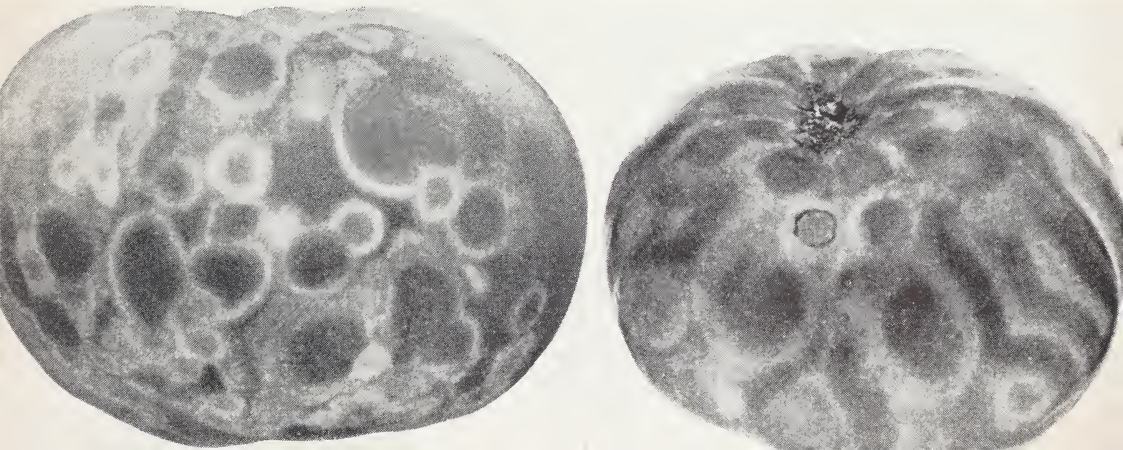
Control.—Field dusting with DDT reduces the percentage of infection, but has not proved to be a satisfactory control even when as many as 6 applications have been made. In the greenhouse, spotted wilt may be controlled by fumigating once a week or oftener to kill thrips.

Preventive measures.—Locate plant beds for tomatoes as far away as possible from home gardens or flowers that harbor thrips.

One variety—Pearl Harbor—is fairly resistant to spotted wilt, especially to early infection. It bears abundantly, but the fruits are small except under very favorable growing conditions.

Curly top in tomatoes is caused by the same virus that causes curly top in sugar beets. It is spread by the beet leafhopper, and is the most serious tomato disease in the southern part of the San Joaquin Valley. During certain seasons, it may also infect the late crop in the northern part of the valley, especially near the foothills, and early tomatoes throughout the valley. The disease may also appear in the Sacramento Valley and south of the Tehachapi range. Infected plants usually do not die, but they

Fig. 38. Spotted wilt on tomatoes. Circular and concentric chlorotic patterns on green fruits.



are a total loss so far as marketable fruit is concerned.

The prevalence of curly top depends upon the number of infective leafhoppers that invade the fields. In the spring, the leafhoppers move from weeds, in their natural breeding areas, to cultivated sections. The principal natural breeding areas are the foothills along the northern part of the San Joaquin Valley, and the valley floor at the south end. In addition to tomatoes and sugar beets, melons, spinach, flax, and many ornamentals and weeds are susceptible to the curly top virus.

Symptoms.—The leaflets roll in toward the midrib (fig. 39) which, together with the leaf stem, curves downward. This gives the leaf a drooping, but not wilted, appearance. Leaves become thick, stiff, and yellow. The plant becomes erect and rigid, and is stunted because all growth stops. The leaf veins and stems turn purple. Infected plants are stiff and brittle to the touch, and rattle when shaken. Most of the infection occurs during the early growth of the plant, and infected plants bear little or no fruit. What fruits are produced ripen when very small.

Fig. 39. Dwarfed tomato plant naturally infected with curly top virus. Leaves roll inward.

The beet leafhopper lives only a short time on tomatoes, and there is relatively little spread of the virus from one tomato plant to another. Most of the danger comes from leafhoppers that enter tomato fields from beets or other crops infected with curly top. Tomatoes often become infected after the harvest of beets in near-by fields.

Control and preventive measures. To date, there is no adequate means of controlling or preventing tomato curly top.

Tomato mosaic, a virus disease, is more prevalent and widespread, but less destructive, than either spotted wilt or curly top. It is not confined to any special areas of the state. This disease is easily spread by contact, such as handling the plants when setting them out in the field. The mosaic virus is occasionally seedborne, and one seedling among hundreds may be infected. A few of these seedlings in the plant beds are a dangerous source of infection when plants are set out in the field. There is also evidence that, in field seeding, the cultivator may spread infection along the row from an occasional infected plant.

The mosaic virus is prevalent in the tobacco crop. Because it withstands prolonged drying, it is present in much commercial smoking and chewing tobacco, an important source of infection for tomatoes. Workers who have handled cigarette, cigar, pipe, or chewing tobacco may infect seedlings while they are being transplanted to the plant bed, and may spread the infection still further in pulling the transplants and setting them out in the field.

Fig. 40. Fernleaf, or shoestring, mosaic caused by the cucumber mosaic virus spread by aphids in the plant bed.

Symptoms.—The leaflets become mottled and puckered, and the plant is slightly reduced in size and yield. Some strains of the virus cause a rather brilliant mottling of the leaves similar to that in yellow or aucuba mosaic. This type frequently produces a faint calico pattern in the fruit coloring, which usually, but not always, disappears at maturity.

Early in the season, when the weather may be cloudy and temperatures low, the foliage symptoms are more extreme, and may be mistaken for fernleaf mosaic. Later foliage, however, produced under higher temperatures, shows typical mild mottling.

Preventive measures.—Anyone working with tomatoes should wash his hands with ordinary laundry soap before handling the plants. This removes any virus which may be on the hands after using tobacco.

Direct field seeding, which eliminates handling, greatly reduces the amount of mosaic.

Fig. 41. Effect of fernleaf mosaic on tomato fruits.

Fernleaf mosaic is caused by the virus of western cucumber mosaic. It is carried by aphids, usually in the plant bed before seedlings are set out in the field. Frequently, a few scattered plants show this shoestring or fernleaf type of mosaic, and heavy outbreaks have occurred in the Brentwood area.

Symptoms.—The plant is greatly dwarfed and the leaflets are so narrow that little more than the midrib is left (fig. 40). The fruits are usually dwarfed and misshapen (fig. 41), and few or none of them salable.

Preventive measures.—Spray plant beds with nicotine or rotenone if aphids are present. Destroy any plants of the cucumber family and any weeds that are near plant beds. Such plants may be sources of infection.

Root rot is caused by Rhizoctonia, Fusarium, Pythium, and possibly other soil fungi, and results in serious losses in tomato fields. It is likely to be most serious on heavy, poorly drained soils. Heavy irrigation early in the season may leave the subsoil waterlogged. When the plant roots come into contact with such soil, they may be subject to attack from soil-rotting fungi. Thus the plants do not develop a normal, deep root system, and may wilt and die as they grow larger, because their shallow roots cannot supply them with enough water for normal growth (fig. 42).

Roots of tomato plants may also die because of insufficient soil aeration. This condition may result when irrigation water is allowed to stand between the rows for too long a time.

Preventive measures.—Root rot may be overcome to a great extent by following the practice of frequent, light irrigations when plants are small, rather than of a few heavy irrigations. This prevents waterlogging of the subsoil, and allows normal, deep root development. Use a soil auger to test the subsoil for water content, in determining the plants' irrigation needs.

Blossom-end rot is apparently caused by high temperatures and insufficient soil moisture and usually occurs on the first fruits that set. In some fields, it appears to have resulted from delaying the first irrigation too long. This disease is not infectious, but by killing fruit tissue, it provides a point of entry for rot-producing fungi which aggravate the trouble.

Symptoms.—Surface tissues at the blossom end of the fruit die, forming a large, flattened, brown area (fig. 43).

Yellowing and sunscald.—When the older leaves of the tomato plants die too soon, the fruits are exposed to the sun. This exposure may cause two types of injury. Usually, the stem end of the fruit

Fig. 42. Root rot causes death of plants in wet soil.

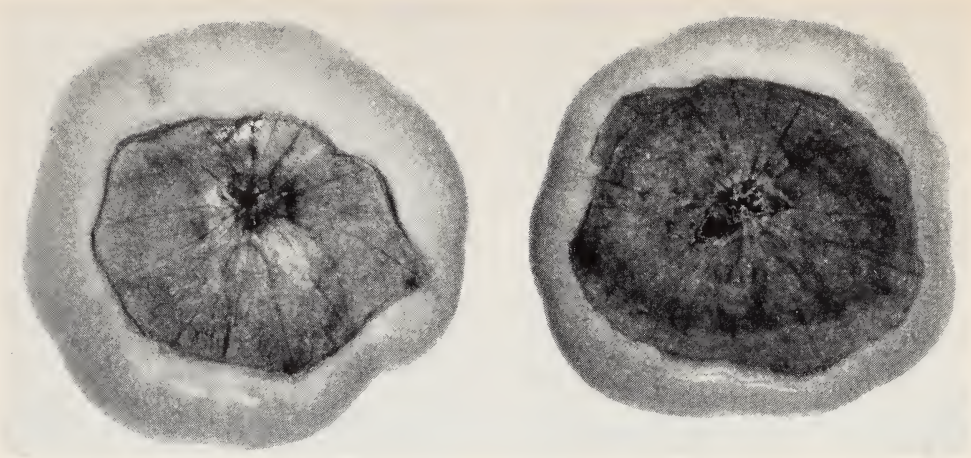


Fig. 43. Symptoms of blossom-end rot on tomato fruits.

does not turn red, but remains yellow (fig. 44). Often, however, the injury is more severe, and the exposed side of the fruit may develop a large, light-colored, dead area (sunscald). This area is often invaded by molds.

Growth cracks and catface.—Growth cracks at the stem end of the fruit provide an entrance for rot-producing organisms. Catface is an enlarged, ugly scar at the blossom end.

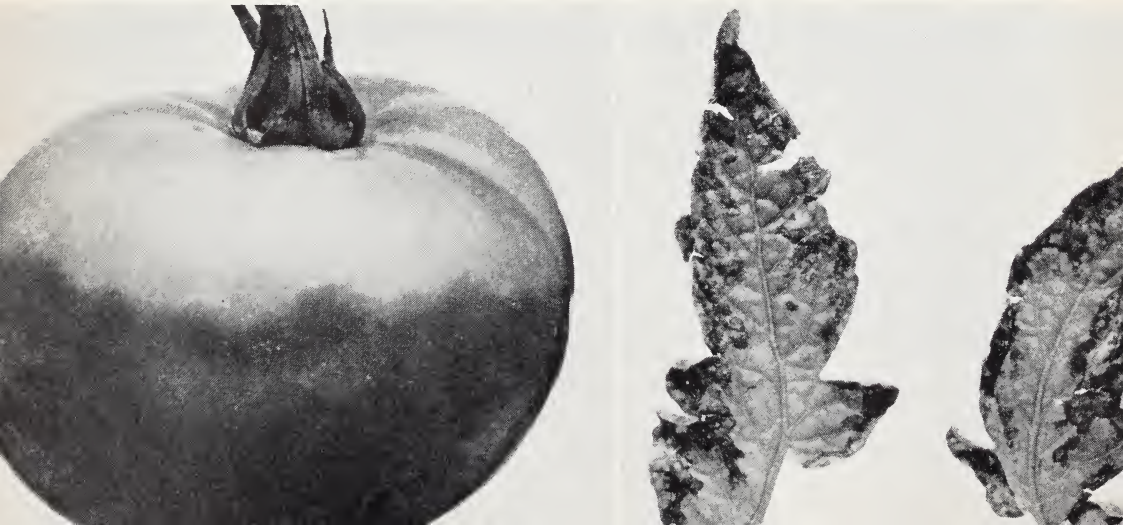
Alkali injury.—In certain areas of some fields, the margins of the tomato leaves show browning (fig. 45) which tends to extend in between the veins.

Psyllid yellows is not a virus disease, but is caused by an insect, the tomato psyllid. Apparently, as the psyllids feed, they inject some toxic substance into the fruit. This disease occurs mainly under cool coastal conditions, and in the early crop near the Salton Sea.

Symptoms of this disease are somewhat like those of curly top, but the young leaves are more purple, leaves and stems are not so brittle, and the plant will resume normal growth if the psyllids are killed. The very young leaflets are puckered, dwarfed, and folded upward along the midrib. The leaf stems are curled and twisted. At this time, the margins and veins of the leaflets become purplish.

Control.—Sulfur dust has been found to be effective against psyllids.

Fig. 44. Left: Yellow-end (or green-end) caused by exposure to sun. Stem end does not color properly when fruit ripens. Fig. 45. Right: Marginal and interveinal browning of leaflets probably caused by excess alkali in the soil.



INSECTS ATTACKING TOMATOES

Two types of insect damage affect tomatoes in California. Direct damage is caused by insects that feed on roots, foliage, or fruit. Indirect damage is caused by certain insects that transmit virus diseases. The latter are discussed under the section on tomato diseases (page 35).

The control of many tomato insects and related pests has been investigated and much information has been obtained on the effectiveness of various insecticides and the proper time of application under northern California conditions.

The tomato insect control program has undergone a marked change since the development of new insecticides, such as DDT and DDD. These have proved to be, on the whole, much more effective against tomato pests than were the old, standard insecticides, such as calcium arsenate and cryolite. Furthermore, the hazard of drifting dusts appears to be less with the new materials than with calcium arsenate. Although the new insecticides look very promising, they have not been in use long enough to warrant any final statement concerning their use in the tomato insect control program. *They must still be used with caution.*

During the past two years there has been, on occasion, a marked increase in a leaf miner infestation on tomato. Also, there has been some evidence that spider mites have increased, and the same appears to be true of certain other pests not usually destructive to tomato. It is not known, at present, whether any of these pests will become major problems, or whether widespread applications of DDT and DDD have in any way affected their increase. It is interesting to note that although nearly the entire tomato acreage was treated with these insecticides in 1949, the problems encountered were fewer than those in 1948. However, until more is known concerning the full effect of the new insecticides, it is suggested that their use be limited to late-season applications for the control of caterpillars, and that the older, standard materials be used in the early-season control program. This division allows for the use of the new insecticides during the most important and critical time. Even during that period, however, they should not be applied without good reason, and never at a higher dosage than the one recommended. Although DDT is not recommended for general use in early-season treatments, it might, under conditions of severe infestation, be lightly and evenly applied for the control of certain pests, such as flea beetles.

The control of tomato pests naturally falls into an early- and late-season program. The pests involved early in the season are usually different from those encountered later after the plants are well established in the field. Early-season pests attack from the time the seed is sown until the plants have become well established in the field. The more important ones include the seed-corn maggot, cutworms, darkling ground beetles, thrips, flea beetles, and wireworms. Aphids, vegetable weevils, grasshoppers, slugs, and snails are sometimes annoying, and under certain conditions the tomato mite may require an early treatment.

The late-season program covers the period from about June 15 to the end of the growing season. The important pests at this time are the tomato mite and a number of species of caterpillars which, if left unchecked, would destroy the crop in many cases.

EARLY-SEASON PROGRAM

Insects and other pests are not always troublesome either in plant beds, after transplanting to the field, or even where the seed is planted directly in the field. However, a grower should watch his plants carefully and be prepared to take

action if a serious situation is indicated. The presence of a few insects does not necessarily mean that a destructive population is developing, because in any plant bed or field a few pests of one kind or another can usually be found. Therefore, the finding of an insect or two should be no cause for alarm, although a very few grasshoppers have been known to be highly destructive to a germination stand of field-sown tomatoes.

Darkling ground beetles.—These are small, dull black or bluish-black beetles that measure scarcely ¼ inch in length. They live in and on the surface of the soil and are destructive chiefly because they eat off or girdle plants just above the ground level. Damage usually occurs after the tomato plants are transplanted in the field.

Control.—If this pest is suspected, dust the base of the plants and the soil about them thoroughly with hydrated lime the same day the plants are set in the field.

Flea beetles.—These are small, dark colored beetles that measure only about 1/16 inch in length. They jump like fleas, especially when disturbed, and damage tomatoes by eating small round holes in the leaves. Where an infestation is severe, defoliation may result. Injury usually occurs after transplanting and during the period when the plants are becoming established.

Control.—Dust the plants thoroughly with a 50 per cent cryolite dust or with calcium arsenate. Under severe conditions of infestation, a 5 per cent DDT dust may be used, but to prevent plant injury apply it thoroughly but lightly.

Vegetable weevil.—This is a brown or buff-colored snout beetle that measures about ⅜ inch in length. It is sometimes destructive in localized areas.

Control.—If control is needed, treat the plants with a dust that contains at least 50 per cent cryolite. To insure protection, cover the foliage and the ground about the base of the plants thoroughly with the dust.

Wireworms.—These are the immature stages of "click beetles." They have smooth, shiny, cylindrical bodies, tough skin, and are usually yellow or brownish in color. They live in the soil and most of the destructive species measure 1 inch or less in length. They injure plants either by cutting off roots or by penetrating into the root and up into the stems of young tomato plants. Wireworms are most likely to be a pest on the lighter soil types. Injury may occur in the seedbed, although the bulk of it takes place in the field after transplanting.

Control.—The method of control used depends upon whether treatment is made before planting or at the time of setting out transplants. Before field seeding, plant-bed seeding, or setting out transplants, several methods may be used.

1. Fumigate with ethylene dibromide mixture at the rate of 2 gallons of actual chemical per acre, or with dichloropropene mixture at the rate of 40 gallons per acre, using field fumigating equipment. In seed beds, use hand weed-gun applicators. Allow at least two weeks to elapse between fumigating and planting.

2. The use of lindane, DDT, chlordane, or other chemicals applied to the soil surface and disked into the soil should be limited to seed-bed treatment unless otherwise recommended by local agricultural authorities. For seed-bed treatment, lindane sprayed on the surface of the soil, at the rate of 0.5 pound per acre, and worked into the upper 2 to 3 inches just before seeding, has proved effective.

3. Tomato seed can be treated with lindane at the rate of 8 ounces of 25 per cent powder to 100 pounds of seed. This treatment controls wireworms attracted to the seed at the time of germination. Lindane can be used with the standard fungicides in seed treatment.

The water applied at the time of transplanting in beds or in the field can be treated with lindane at the rate of 1 ounce of 25 per cent material in 100 gallons of

water. This treatment is effective and to date has given no indication of affecting growth or imparting off-flavors. Growers should proceed with caution, however, as adverse effects may occur which cannot be foreseen at this time. In peat soils, one-half again of the suggested dosage may be necessary for control.

Crickets.—These large, brown to black, swiftly moving insects with long antennae or feelers are so well known that a detailed description is not needed. They feed at night and are likely to be most troublesome in warmer climates and in regions where there is considerable uncultivated land. Most damage is done at the time of transplanting, and where abundant, crickets will cut off the newly set out seedlings.

Control.—Poison bran baits will give some relief, but if they are to be at all effective they must be applied several days in advance of transplanting. The dust treatment, as recommended for the control of darkling ground beetles, gives protection. Dusts that contain chlordane are also effective against crickets, but if you use them, follow the directions on the container carefully.

Seed-corn maggot.—This pest is a larva of a fly. It is legless, has no distinct head, and is nearly white. The seed-corn maggot attacks the germinating seeds and roots of tomato, and is a pest during the seed bed period. Injury by the pest is encouraged by cold, moist, poorly drained soils.

Control.—No highly satisfactory control of this insect has been developed. If you think the pest is present, some relief may be obtained by dusting plants lightly but thoroughly with a 5 per cent chlordane dust. To prevent injury, do not over apply the insecticide.

Cutworms or armyworms.—These insects are the caterpillar stage of a group of medium-sized, dull-colored moths. Those important in the early season are night-feeding species, which are somber in color and when full-grown are 1½ to 2 inches long. During the day, they hide in the soil and debris. Cutworms cause injury by cutting off the young seedlings or newly transplanted plants below or above ground. They also feed on the foliage, and while a plant may not be cut off, it may be seriously defoliated. Injury by cutworms is most likely to occur where weedy fields, or fields containing considerable growing vegetation or sod, have been recently prepared for planting.

Control.—If cutworms are thought to be present, scatter a commercially prepared poison bran bait over the field at the rate of 25 pounds to the acre. This should be done just before dusk several days before transplanting. Dusts used according to recommendations for the control of flea beetles should be of some benefit if the plants have already been set out.

Aphids.—These are such familiar pests that there is no need to describe them. They obtain their nourishment by inserting their needle-like mouth parts into the plant tissue and sucking the plant juices. Aphids cause damage indirectly by transmitting a virus disease of tomato, but they rarely suck up the plant juices sufficiently to cause direct damage of an economic nature. Frequently, following transplanting, many aphids may be found on the recently set out plants. These usually prove to be the green peach aphid which has migrated from other hosts. Such infestations usually die out and control measures are seldom, if ever, necessary. Another aphid sometimes encountered is the potato aphid. Only rarely has it been found in destructive numbers.

Control.—Where control is necessary, apply a number 10 (4 per cent actual nicotine) nicotine dust.

Thrips.—These are small, slender insects with mouth parts developed primarily for sucking. They are about $\frac{1}{25}$ of an inch long, and the adults have two pairs of fringed wings, carried lengthwise over the back. Both the young and the adults cause damage. Their rasping

and puncturing of the surface cells result in a silvering of the leaves, stems, and fruit. Besides causing this direct injury, thrips transmit the serious spotted wilt virus disease of tomato, and once a plant is infected, there is nothing that can be done to stop the disease.

Thrips are common insects that can be found in most tomato fields. Usually they are not present in destructive numbers, although occasionally injurious populations are encountered. Where growing and cultural conditions are excellent, the plants will usually outgrow the injury caused by feeding.

Control.—Where injury is severe, some relief can be obtained by thoroughly dusting the plants with a number 10 nicotine dust (4 per cent actual nicotine). A 5 per cent DDT dust, lightly and evenly applied, will give excellent control, but its use is not recommended unless a very serious infestation is encountered. The DDT dust should contain 50 per cent sulfur as a control for the tomato mite.

Grasshoppers.—Occasionally, grasshoppers may be destructive. Where control is required, application of chlordane at the rate of 1½ pounds of actual material, per acre, has given satisfactory results. Promising results have also been obtained with toxaphene.

Tomato psyllid.—This insect is about the same size as aphids, to which it is closely related. The adults resemble miniature cicadas and are grayish marked with white. All damage is done by the small, flat, elliptical, scale-like nymphs or immature forms, which vary in color from light green to orange. The nymphs are somewhat similar to those of certain whiteflies, and are normally found on the undersurface of the leaves. They have a row of wax glands, and when there is a large infestation, the white wax which is secreted may be seen on the leaves and even on the ground about the plants. The nymphs obtain nourishment by sucking cell sap, and cause injury by injecting a toxic substance into the plant. This causes a stunting of the plant and a yellowing and curling of the leaves—a condition known as "psyllid yellows." Damage by this pest in California is localized and is usually limited to the cooler coastal regions.

Control.—Dust the plants thoroughly with sulfur. Begin applications when the first evidence of infestation is detected, repeat at two-week intervals until the pest is thoroughly controlled.

Snails and slugs.—These well-known pests have chewing mouth parts and feed chiefly at night. They are seldom a pest of tomato, although they have occasionally caused annoyance about seed beds. In the presence of high moisture conditions and dense foliage, slugs have been found feeding on fruits of tomato in the coastal area.

Control.—Where control is needed, scatter a commercially prepared poison bran bait over the infested area. This bait should contain both calcium arsenate and metaldehyde. For best results scatter the bait at dusk on wet ground.

Tomato mite.—This pest is considered more fully in the section, "Late-Season Control Program" (page 53). It is mentioned here because, under certain conditions, it may become a pest in the early season. Petunia is an important overwintering host of the tomato mite, and therefore tomato beds should not be located near such plantings. If possible, petunia plants near tomato fields should be destroyed.

Control.—If a tomato mite infestation should be detected, it can be controlled promptly by treating the field thoroughly with a sulfur dust.

Root-knot nematode.—This parasite, which attacks the roots of many kinds of plants, is a small, round worm of almost microscopic size. It causes the formation of gall-like swellings or knots on the roots of tomatoes. The adult nematodes are imbedded in these galls. Heavily infested plants become weakened and may eventually die. The first above-

ground indications of the presence of this pest are poor growth, stunting, and the yellowish appearance of the plants in the field.

The tomato is very susceptible to injury by the root-knot nematode and should not be planted in fields known to be heavily infested. It is frequently possible to secure reasonable control of this pest by growing such unfavorable host crops as barley, wheat, oats, and other grains before the tomato crop is to be planted.

Control.—The root-knot nematode can be controlled by the fumigation of the soil with certain chemicals. The most effective of these are the fumigants which contain 1, 3, dichloropropene, sold under the trade names of Shell D-D and Dowfume N. These materials usually give satisfactory control of root-knot nematode when applied at the rate of 200 pounds per acre. Ethylene dibromide mixtures are also effective under conditions of moderate infestation, particularly in the coastal areas. Application is usually made at the rate of 3 to 3½ gallons of actual ethylene dibromide per acre. In general, fumigation is effective for only a single season. Special commercial applicators are available for applying the above-mentioned fumigants.

Caution: These fumigants are toxic to plants, and a field should be treated at least two weeks in advance of planting. Where trees and shrubs are growing nearby, treatments should not be made within the drip areas of such plants. The chemicals are also toxic to man. If they are spilled on the skin, wash the affected area thoroughly with soap and water. Clothing that has come into contact with fumigants should be cleaned or washed before being worn again.

LATE-SEASON PROGRAM

This is the most critical period in regard to the control of insect and related pests of tomato. Usually, during this time, a serious attack by one or more of the pests can be expected. The severity of the infestation by the several pests varies from district to district and year to year, but in all cases a grower must be prepared to combat attacks.

The first pest to be encountered is the tomato mite, followed through the season by a number of caterpillars that must be controlled. The most important of these are known by the common names of yellow-striped armyworm, beet armyworm, alfalfa looper, various night-feeding cutworms, tomato pinworm, potato tuber moth, tobacco hornworm, tomato hornworm, and the corn earworm. The pests and their habits will first be considered, and this will be followed by a program designed to give efficient control throughout the entire late season.

The tomato mite feeds and reproduces on a number of cultivated plants, notably tomato, potato, and petunia. It reproduces from eggs, and passes through many generations in a season. Continuous reproduction has been reported from early May until frost.

The mite is too small to see with the

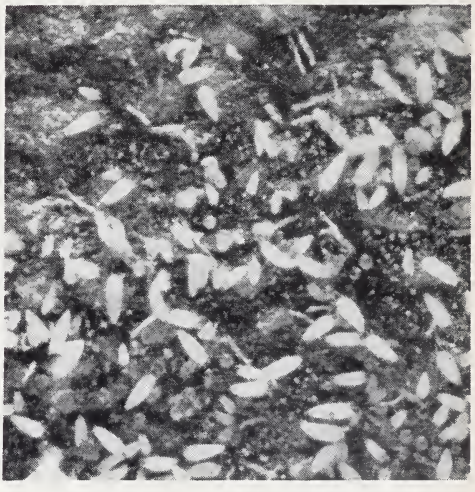


Fig. 46. The tomato mite, enlarged 40 times. (From Bul. 707.)

naked eye, but under the microscope it appears as somewhat pear-shaped, and tannish-white in color (fig. 46). It crawls about slowly on the surface of the leaves, stems, and fruit of the tomato plant and sucks out the cell contents. The infestation usually starts near the ground and, as it progresses up the plant, the lower leaves become dry, giving the plant an unhealthy appearance. The color of the stems and leaves frequently becomes greasy bronze or russet.

If not controlled, the pest causes serious defoliation which is particularly rapid during periods of hot weather. The result is sunburned fruit and crop loss.

Tomato mite appears early in tomato fields and usually requires control measures in advance of most of the other pests.

The caterpillars.—The caterpillar is the second of four distinct stages of development which butterflies and moths go through: egg, larva (caterpillar), pupa (chrysalis), and adult (moth or butterfly). Damage is inflicted only during the larval, or caterpillar, stage. Moths lay the eggs but do no damage. However, they must be recognized as a warning of the caterpillars to come. The control program must be directed against the caterpillars themselves.

The life histories of all of the caterpillars are somewhat similar. Eggs, which have been laid on the plant by the adult moths, hatch after three to five days. The small caterpillars eat their way to maturity, casting their skins several times as they grow. During this period they do their damage to plant, leaves, or fruit, each in his own way.

On completing development as larvae, the caterpillars begin construction of their pupal cells. Most of the pests of tomato will burrow into the soil, build their cells a few inches below the surface, and construct tunnels upward to within one-half inch of the surface for the subsequent emergence of the adult moth. The alfalfa looper, however, spends its pupal life in a light silken cocoon it has spun in a fold of a leaf, or in several leaves tied together, or in the debris under the plant. The pupae of the tomato pinworm and the potato tuber moth, on the other hand, are usually to be found at or near the soil surface.

The pupal stage varies in length for each of the different kinds of caterpillars, and also varies with the weather. For example, the corn earworm has a pupal period of two to three weeks during the summer, but the fall broods will remain in this stage over winter.

Egg laying begins.—When the pupal stage is over, the adult moths emerge, expand and dry their wings, mate and, after a day or two, begin to lay their eggs in great numbers. Usually at dusk on warm days the female moths of the corn earworm may be seen flitting here and there,

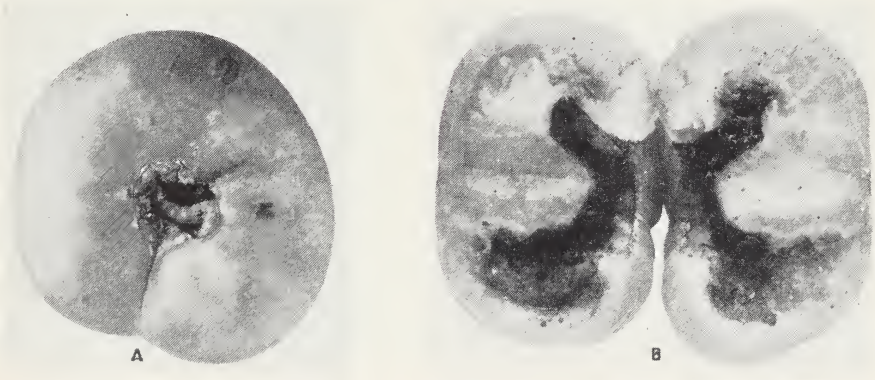


Fig. 47. Corn earworm (A) may spend its life in the fruit, causing damage shown at right (B). (From Bul. 707.)

seldom flying higher than the tops of the plants, and laying eggs at random over the vines. A single moth will lay 500 to 3,000 eggs during her lifetime.

With the hatching of these eggs, another generation begins its life cycle. Some species, such as the tomato hornworm, have three generations a season, but others, such as the tomato pinworm, pass through as many as seven or eight generations in a year.

Know the pests by the damage they do.—While the life histories of all of the caterpillars are quite similar, the damage they inflict on tomatoes may differ widely. The visible evidence of this damage serves as the best clue to the kinds of pests present, and indicates the kind of treatment which should be applied.

Corn earworm.—The corn earworm is considered the most destructive caterpillar because of its abundance and wide distribution, and the fact that it normally completes its entire larval development in the fruit. This pest prefers corn and beans, and turns to tomato late in the summer when the former crops have passed their maturity and are drying up. If it becomes established in the tomato fields in August, there is still sufficient time for two broods to appear before tomato harvest is completed. Where infestation is severe, more than 50 per cent of the tomatoes may be destroyed.

The larvae usually enter at the calyx or stem end (fig. 47) and some are so small at the time they infest the fruit that one must look carefully to detect the point of penetration. The caterpillar may emerge from one fruit and enter another. The small corn earworm tends to enter developing tomatoes ¾ to 2 inches in diameter. Therefore, the beginning of an infestation can be determined by picking and thoroughly examining fruit in this size range. A control program need not be started until 1 to 2 per cent of the fruit in this stage of development shows signs of infestation. Pick at least 300 fruits at random throughout the field to determine the degree of infestation. Late in the harvest season, the small larvae may enter the ripe fruit as well, causing the canner much annoyance because these infested fruits are nearly impossible to detect.

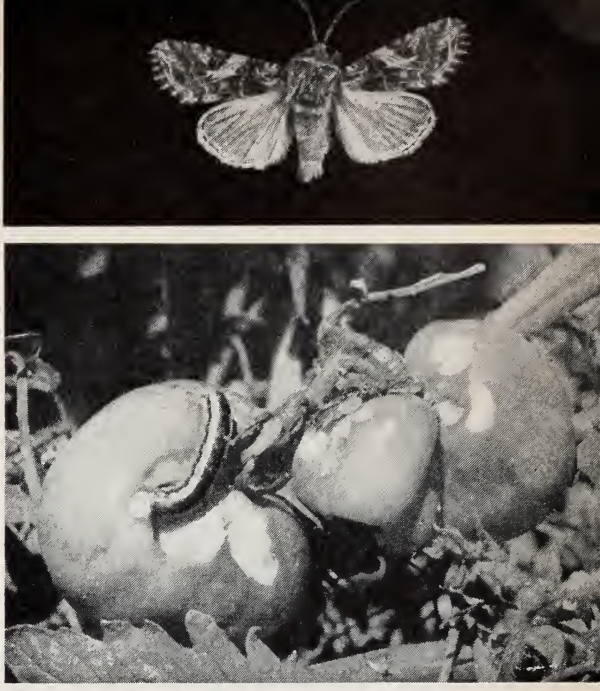


Fig. 48. Yellow-striped armyworm. Above: Moth of this species is grayish in color. Forewings have slate and buff markings; hind wings are silver and gray. Below: Typical injury to tomato by caterpillar. (From Bul. 707.)

Yellow-striped armyworm.—While occurring in greatest numbers on alfalfa, the yellow-striped armyworm infests many kinds of cultivated and native plants. Although not a serious pest of tomato every year, on occasions it is very destructive. Infestations in tomatoes arise from moths which fly into tomato fields, or from caterpillars which migrate from adjacent alfalfa fields when the latter are cut.

This pest feeds both on the foliage and on the fruit of the tomato. It does not enter the fruit, but eats irregular holes in its surface (fig. 48). Its most serious attack on tomato occurs from July through the middle of September.

Beet armyworm.—One of the most common and widespread pests in Califor-

nia, the beet armyworm, is to be found in tomato fields every year. At times, in certain fields, it has been the most important caterpillar attacking tomato.

The beet armyworm feeds primarily on foliage, but it will also seriously attack the fruit in which it eats single, or closely grouped, circular or irregular holes. In many cases the feeding is only superficial, and there would be little loss if rot and decay did not enter the wounds.

This pest is most common and destructive in the warmer interior valleys where it is abundant from late July until early November. In severe cases of infestation it is not uncommon to find an average of 25 to 50 caterpillars to a tomato plant.

Alfalfa looper.—These caterpillars are easily distinguished from others because they arch their backs when they crawl, hence the name "looper."

The alfalfa looper eats foliage and rarely feeds on fruit. It occurs in fair abundance, but seldom causes enough damage to require special control measures.

Potato tuber moth.—Tomatoes over a large portion of California are subject to infestation by the caterpillar of the potato tuber moth. They appear to be most prevalent in the coastal regions and the San Joaquin Valley.

There is always the danger of a serious infestation developing where tomatoes follow potatoes and where there are volunteer potato plants. Usually, less than 5 per cent of the tomatoes in a field show infestation, but damage to as high as 57 per cent of the fruit has been found.

These larvae prefer to enter the fruit at the calyx end and make a dry burrow through the core and the fleshy portions which radiate from it (fig. 49). They may enter at any point, however. They usually spin a web over the entrance to their burrows, if these are exposed. The fruit must be carefully observed to detect damage.

Tomato pinworm.—This caterpillar is a leaf-miner and leaf-folder, but during the last half of its larval existence it also frequently bores into the fruit.

Where abundant, the tomato pinworm may cause serious damage to the foliage, and nearly 100 per cent of the fruit may be infested. The larvae will enter the fruit at any point. They make dry burrows, are small, and usually do not penetrate very far into the fruit.

After an infested fruit is picked, the caterpillar quickly spins a web over the entrance to its burrow, making its presence hard to detect.

Because the pinworm completes a number of generations in a season, it becomes more serious as the season advances. Greatest damage is likely to occur where tomatoes are produced from early in the growing season to late in the fall.

Night-feeding cutworms.—There are several species of cutworms which attack tomato only at night, and hide in the soil or surface debris during the day.

Fig. 49. Injury caused by the potato tuber moth. (From Bul. 707.)

Fig. 50. Defoliation like this is typical hornworm injury. (From Bul. 707.)

Under some conditions they are likely to be quite destructive.

These pests injure tomatoes by eating irregular holes in the surface. Tomatoes that rest on the ground are, in general, the most seriously injured.

Hornworms.—The tomato hornworm and tobacco hornworm are similar at all stages of development, and their damage to tomato is also similar. They feed on the blossoms and fruit but cause the most serious damage by stripping the leaves from tomato vines. If severe infestations go unchecked, hornworms may defoliate an entire field (fig. 50).

Hornworms are particularly serious pests in the warmer interior valleys of the state.

NATURE AND CULTURAL METHODS AID PEST CONTROL

Control of caterpillars attacking tomato would be a much more difficult problem if it were not for natural factors which tend to hold destructive pests in check. Important among these are predators, parasites, and diseases. Weather, also, may have an adverse effect.

In spite of these natural limiting factors, some of the many pests are likely to reach a destructive level. The tomato grower can meet the problem in two ways. He can adopt cultural practices which are unfavorable to the pest, and he can employ specific pest-control measures involving the application of effective insecticides.

Natural enemies.—Caterpillars infesting tomato are subject to the attack of a number of parasites and predators. The full value of these enemies has never been determined, but it is known that certain of them are responsible in a large measure for some species of caterpillars not reaching a destructive level every

year. One of these, *Hyposotor exiguae* (Vier.), which attacks the corn earworm and the yellow-striped armyworm, has been observed, and is recognized as an important factor in controlling these pests.

The action of the many parasites upon their host, and the influence they exert in regulating populations is a subject that is in need of thorough investigation. It is important that insecticidal control programs be developed that will supplement the work of the natural parasites.

Cultural methods.—The destruction of crop refuse is a sanitary measure that should be practiced. It is particularly important in regions where tomato pinworms or the larvae of the potato tuber moth are a problem. Where the pinworm is a pest, growing of an early- and late-season crop should be avoided if this is at all possible. If two crops are grown, destroy the refuse from the first crop by burning it or plowing it under just as soon as the harvest has been completed.

The practice of following potatoes with tomatoes should be avoided. Most extensive damage by the larvae of the potato tuber moth has usually been found in those fields where volunteer potato plants have been growing.

Infestations by the corn earworm on tomatoes are likely to be most severe in areas where sweet corn and beans are grown. The farmer must encourage the destruction of crop refuse as soon as these preferred hosts are harvested.

INSECTICIDE CONTROL PROGRAM

The late-season control program should be well-integrated so that the crop will be protected from all the important pests throughout the entire bearing season. The first pest that must be considered is the tomato mite. This pest can be controlled by treating the fields with sulfur. Treatment should be applied not later than July 15, and in all cases before injury by the mite becomes apparent. If insecticides are incorporated with the sulfur, for worm control, the sulfur content of such dusts should be 75 per cent. Under no condition should the sulfur content be less than 50 per cent. If liquid applications are used for this early treatment, apply at least 15 pounds of wettable sulfur per acre. To insure good control of the tomato mite, the second dust application which is directed against caterpillars should contain 50 per cent sulfur. If a third dust application is made for caterpillar control, sulfur may be omitted if there is no evidence of a developing tomato mite population.

The two most thoroughly commercially tested and effective insecticides, with one exception, for the control of caterpillars are DDT (dichloro-diphenyl trichloroethane) and DDD (dichloro-diphenyl dichloroethane). These insecticides have resulted in good control where applied as dusts or concentrated sprays at the rate of 1½ pounds of actual material per acre per application. This is equivalent to 30 pounds of a 5 per cent dust, or 3 pounds of a 50 per cent wettable powder. Where coverage has been good, satisfactory control has been obtained with either ground or airplane application. With concentrated sprays, 3 pounds of a 50 per cent wettable powder have been used with 10 gallons of water.

DDT dust is highly effective against all the important caterpillars with the exception of the tomato hornworm *Protoparce sexta* (Johan.). When DDT is applied as a concentrated spray, it gives good control, but a 5 per cent DDT dust is not effective in killing the larger, more mature worms. Therefore, a 5 per cent DDT dust should be used with caution in regions where hornworms are likely to be a serious pest.

Another new insecticide that has shown considerable promise in controlling to-

mato caterpillars is a 10 per cent toxaphene dust applied at 30 pounds per acre. This insecticide has been experimented with for three years and the results obtained approach those secured with DDT and DDD. This insecticide has given good control of all caterpillars where it has been used in combination with DDT. A dust that contained 5 per cent toxaphene and 3 per cent DDT, at 30 pounds per acre, produced good results. In sections where hornworms are likely to be a serious pest, and a grower needs to apply a dust, this mixture, or DDD, might be a safer application to use than a straight DDT dust.

The most critical period for caterpillar control is from about July 15 to the end of the season. Satisfactory control of the tomato mite as well as of the several species of caterpillars is usually obtained with not more than three applications of insecticides. Under certain conditions and in certain areas, fewer applications are needed. However, IN NO CASE should the first application, which is mainly directed against the tomato mite, be omitted. Remember: good control is dependent upon thorough and even application of the insecticides.

The following is a generalized program suited to most of northern California.

THE GENERALIZED CONTROL PROGRAM FOR NORTHERN CALIFORNIA

The following schedule for applications of insecticides is particularly adapted to northern California conditions, where canning tomatoes are predominant. In the central and southern San Joaquin Valley the program should be put into operation as early as late May or June, and continued as long as there is evidence of pest damage.

JULY 1–15

Because the tomato mite is the first pest to make an appearance, it should be treated first, by dusting with sulfur. This treatment probably will be needed by July 1 to 15. During this period, hornworms, yellow-striped armyworms, and beet armyworms may be making their appearance. Where this occurs, an effective insecticide should be used in conjunction with sulfur to control them.

AUGUST 1–15

During early August the important insects to control are the beet armyworm, yellow-striped armyworm, and hornworms. A suitable insecticide should be applied to check their damage. At the same time the application will control the few corn earworms which may be appearing. The insecticide should also contain sulfur to continue the control of the tomato mite.

SEPTEMBER 1–15

Early in September a third treatment is needed and is primarily directed against corn earworms, but should also be effective against armyworms and hornworms which are certain to be present. If damage by the tomato mite is not apparent, sulfur may be excluded.

SAMPLING

Any application of insecticides should be based upon a knowledge of the insect pests present.

An examination of from 200 to 600 fruits, depending on the size of the field, should reveal the kinds of insects present and the degree of infestation. These samples should be taken at random from all parts of the field, as incidence of pests may vary widely from one spot to another.

Insecticidal residues.—The question of poisonous residues always arises in connection with the application of insecticides.

The final authority concerning residues is the Federal Food and Drug Administration. Because no tolerance has been announced for the presence of DDT and

related compounds in canned foods, it is imperative that residual amounts of these compounds be effectively removed before the products are canned.

For this reason, residue studies were undertaken to determine the effectiveness of removal of DDT and DDD from tomatoes by washing methods similar to those used in commercial canneries. The testing was done by the National Canners' Association Laboratories, and the results were reported to the authors to supplement their control investigations.

The results of these studies are briefly stated as follows:

DDD and DDT on unwashed tomatoes picked the same day the insecticide was applied showed from 0.2 to 1.7 parts per million; the same fruit after washing showed from 0.1 to 0.7 parts per million. Juice prepared from the washed tomatoes contained 0.1 part or less per million of DDT or DDD; while the residue of the pulp after juice was removed contained from 2.7 to 4.3 parts per million of DDT or DDD. Subsequent studies have confirmed these results and have also indicated that a 10 per cent toxaphene dust can be safely applied to tomatoes.

From the above, it appears that there should be no serious residue problem so far as canning tomatoes are concerned if the insecticides are used as recommended in this circular.

Where fruit is intended for the fresh market it should be washed or carefully wiped.

ACKNOWLEDGMENTS

Dr. MacGillivray wishes to express his appreciation for assistance received from various staff members, and for photographs provided through the kindness of the Associated Seed Growers, Ferry-Morse Seed Company, and the Union Pacific Railroad Company.

Dr. Michelbacher wishes to thank the following growers for their coöperation: Harlan and Dumars of Woodland, Albert Bevis of Patterson, and J. A. Molter of Davis. Thanks are also due to: E. O. Essig, W. W. Middlekauff, W. Harry Lange, Frank C. Lamb, N. B. Akesson, Edward Wegenek, Don Davis, and Charles Hanson; to J. R. Esty, Western Branch Laboratory of the National Canners' Association; and to the insecticide companies who furnished material for use in the investigation.

In order that the information in our publications may be more intelligible, it is sometimes necessary to use trade names of products and equipment rather than complicated descriptive or chemical identifications. In so doing, it is unavoidable in some cases that similar products which are on the market under other trade names may not be cited. No endorsement of named products is intended nor is criticism implied of similar products which are not mentioned.

Coöperative Extension work in Agriculture and Home Economics, College of Agriculture, University of California, and United States Department of Agriculture coöperating.
Distributed in furtherance of the Acts of Congress of May 8, and June 30, 1914.
J. Earl Coke, Director, California Agricultural Extension Service.

30*m*-6,'50(B8980)LL